SURREY SATELLITE TECHNOLOGY LIMITED

Nitrous Oxide Resistojets for Hybrid Rocket Application

Final Report to EOARD

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REFERENCE

EOARD Contract

DATE

1/4/98

PROJECT

N2O Hybrid

REVISION

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

4 January 1998

3. REPORT TYPE AND DATES COVERED

Final Report

4. TITLE AND SUBTITLE

Nitrous Oxide Resistojets for Hybrid Rocket Applications

5. FUNDING NUMBERS

F6170897W0096

6. AUTHOR(S)

Mr. Malcolm Paul

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Surrey Satellite Technology, Ltd.
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8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

SPC 97-4030

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Surrey Satellite Technology, Ltd. as follows: The contractor will investigate N2O combustion initiation processes in hybrid rockets. A modified resistojet was developed for superheating N2O to initiate hybrid combustion.

14. SUBJECT TERMS

Chemical Propulsion

15. NUMBER OF PAGES

51

16. PRICE CODE

N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19, SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

EOARD FINAL REPORT

I. INTRODUCTION

A hybrid rocket engine using the propellant combination of Nitrous Oxide and HTPB represents the least hazardous approach to building and testing of rocket engines.

The usual method of initiating combustion is to supply thermal energy, typically with some form of pyrotechnic, at the start of N2O injection. Once N2O /HTPB combustion has started, the process is self sustaining. However, pyrotechnic ignition is acceptable only for a single shot device , as multiple starts require the complication of a breech mechanism.

An alternative approach to ignition would be to supply the thermal energy directly to the N2O until such time as steady state combustion is achieved.

It is suggested that passing some of the incoming N2O through an electrically heated bed would raise it's temperature sufficiently to sublime the surface of the HTPB and thus start the combustion process.

The RESISTOJET currently under development at SSTL is an ideal candidate device for an experimental program to investigate the suitability of electrical heating for hybrid engines.

This report covers work conducted for EOARD from February 1997 - February 1998

It presents:

- an analysis of initial results predicted for using N2O in the existing RESISTOJET
- describes the Mark-I RESISTOJET test programme
- discusses the Mark-II RESISTOJET test programme
- presents the Mark-III RESISTOJET test programme
- gives conclusions and recommendations for future work
- Appendix with all of the data produced in the programme

This report is expected to fulfill the requirements sent to us in the EOARD SOW regarding this effort under Contract # SSTL1.

II. PREDICTED RESULTS

The theoretical performance of the system can be predicted by using the ISP code developed by Curt Self of the AFRL. Gas temperatures of 800 - 1900 K can produce specific impulses of 110 - 198 sec respectively for nitrous oxide (Isp's of various working fluids is shown below). Using this theoretical Isp and resultant exit velocity, the thrust of the system can be determined as a function of mass flow rate i.e. mass flow rates

ranging from 0.0002 to 0.0011 kg/s produce thrust levels of 0.5 to 1 N respectively. Based upon mass flow rate, and theoretical exit velocity which gives expected chamber temperature, the first order power requirement was obtained from a simplification of the First Law of Thermodynamics:

$$Q = \dot{m} \times C_p \times \Delta T$$

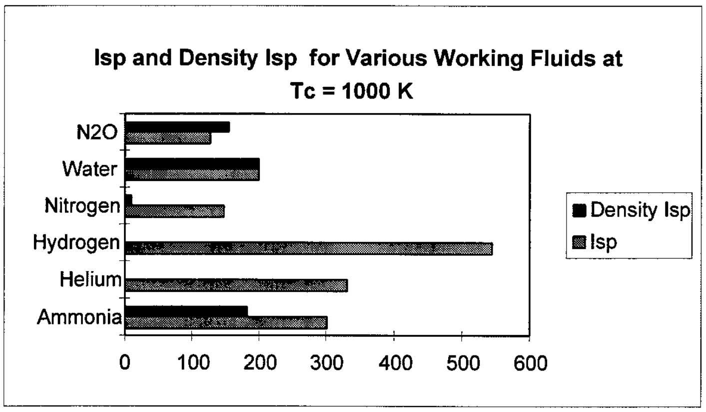
where Q = Power (W)

$\dot{m}$ = mass flow rate (kg/s)

Cp= gas heat capacity (~1100 J/kg @ temperature and 10 bar pressure)

ΔT = Final gas temperature - initial temperature (K)

Based upon our projected mass flows rates, our power requirements should be between 100 to 500 Wat



Our goal was to maximise chamber temperature for the given input power. Nitrous oxide decomposes on heating above 520 C to nitrogen and oxygen. Using Curt Self's Isp code discussed above, the full decomposition temperature is 1900 K which produces an Isp of 198 sec. Since we had no materials that could support those temperatures, we were more interested in characterising the performance on the lower temperature end. The storage density of nitrous oxide at 20 C is 510 kg/m3 at a pressure of 830 psi. This feature allows nitrous oxide to have a good storage density (compared to other gases) and allows it to run on its own vapour pressure (no pressurent system needed).

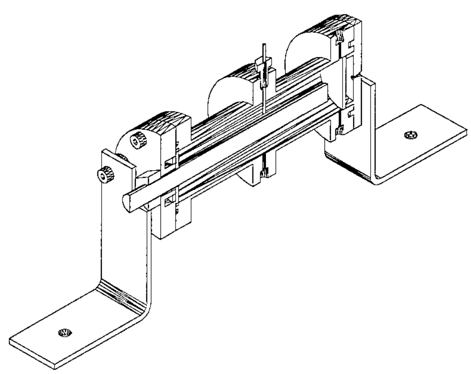
The key test results in the program will be to empirically determine the rate of decomposition of the nitrous oxide as a function of time and mass flow rate at this lower decomposition end. Remember, the gas stream only needs to be 600 C to allow combustion in a hybrid.

II. MARK-I TEST PROGRAMME

The Mark-I test programme was conducted at Royal Ordnance, Wescott UK in March of 1997. We will describe the Mark-I system in detail, and then just discuss the design changes as we went from programme to programme. The Mark-I thrust chamber is 30 mm by 120 mm with a 10 mm by 110 mm commercial cartridge heater installed in the

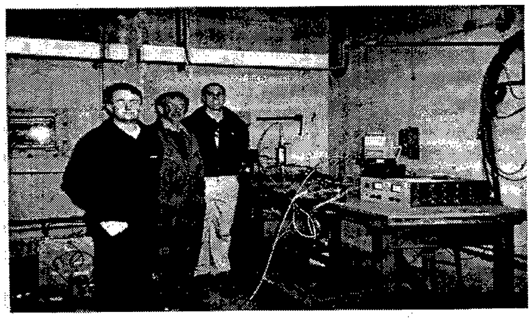
centre provided by Hedin in Essex, UK. A cut-away drawing of the thrust chamber is shown below The chamber is made of 304 stainless steel. The heater is composed of nickel-chromium alloy filament, magnesium oxide insulation, and an Inconel sheath. At 28 V input voltage, it is designed to produce 500 W at a power density of 24 W/cm^2. Around the heater, the chamber is packed with the 350 um SiC (best based upon test results from testing 8 other bed materials). The N2O flow rate can be varied from 0.0002 to 0.0011 (variable area flow meter) at an inlet pressure of 10 bar. An injector was designed with six 500 μm diameter holes to provide a uniform nitrous flow to the bed. As it enters the chamber, the nitrous passes through a 2 mm sintered disk (65% porosity) which keeps the heat transfer material from interacting with the injector and also provides a pressure drop to decouple the inlet pressure from the chamber pressure. The nitrous then flows across the bed, is heated, and passed out through the 0.5 mm throat diameter nozzle (expansion ratio is 25:1).

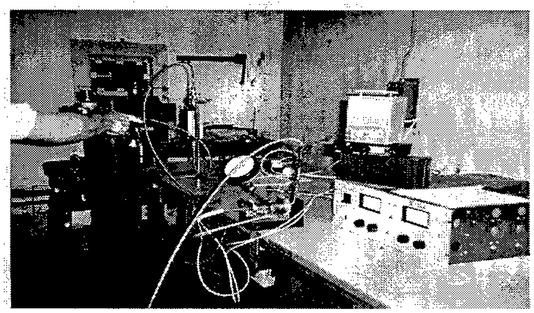
A 50 mesh stainless steel screen has been used at the aft end to contain the heat transfer material. The instrumentation in the thrust chamber consists of three pressure gauges and 2 thermocouples.

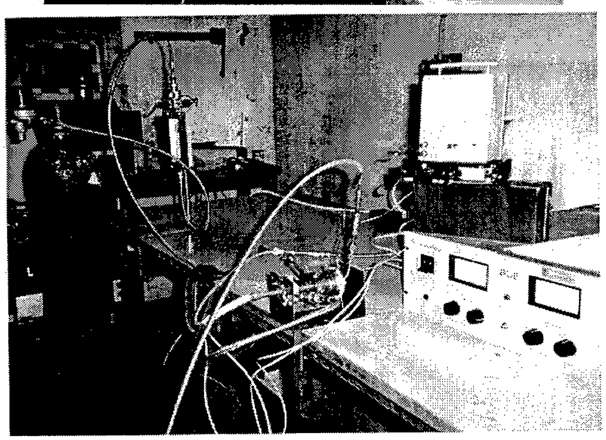


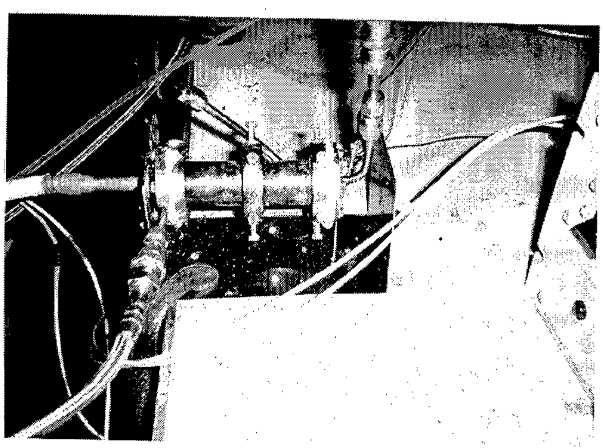
Cut-away diagram of experimental water resistojet

The test apparatus is shown below. All of the tests were conducted at RO Wescott at the J-4 test site.









The power supply is a Farnell H Series 3kW DC power supply unit. (0-60 V DC, 0-50 A).. The power supply console displays voltage and current via a needle display. A standard BOC nitrous oxide cylinder is used to supply nitrous gas to the system. The gas is stored at 48 bar but has a regulator to regulate pressure from between 0 - 12 bar.

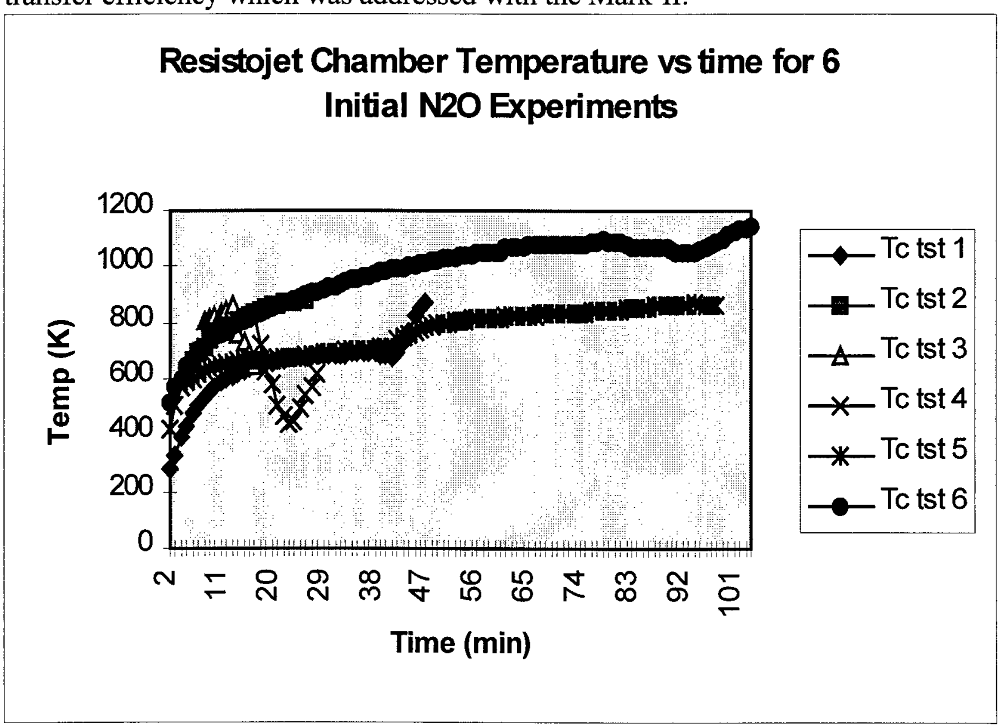
There are 2 valves in the system. Valve 1 is a needle valve used to open pressure from the cylinder to the system and regulates flow through the flow meter. Valve 2 is a stop valve used for safety. Standard ¼" o.d. stainless steel is used for the system plumbing.

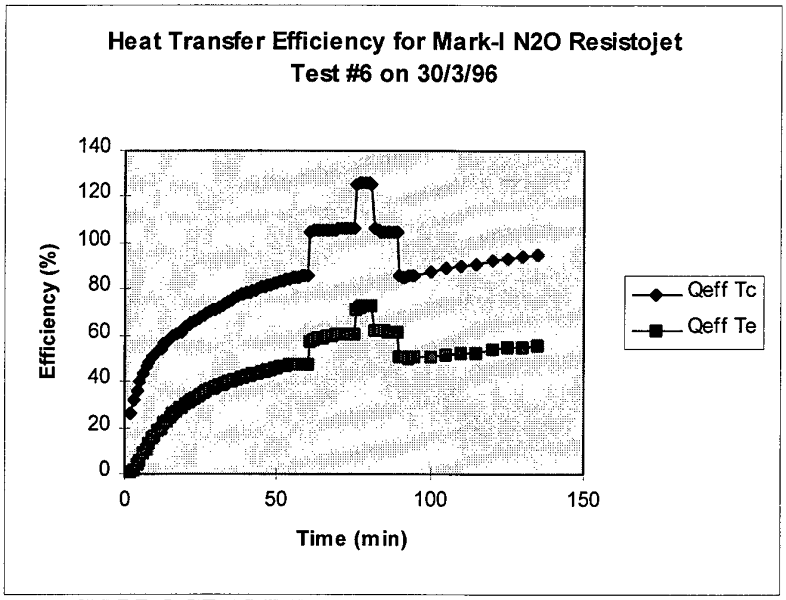
The flow meter used is a Fischer and Porter linear variable area gas flowmeter rated for nitrous oxide at 10 bar within 3 % error.

There are four pressure gauges in the system - one at the regulator; gauge 2 at the inlet to the injector; gauge 3 in the thrust chamber prior to the aft screen mesh or sintered disk (depending on bed material); and gauge 4 aft of that gauge just before the nozzle to measure exit pressure of the chamber.

There are 2 thermocouple locations - 1 in the middle of the chamber and 1 at the aft end of the chamber. These thermocouples are both located at depths of approximately 5 mm from the chamber wall.

The temperature results and efficiencies are shown below. The last test result showed we had just started to obtain decomposition. Unfortunately, the reaction did not hold once we turned the power off. However, the Mark-I had problems with heater life and heat transfer efficiency which was addressed with the Mark-II.



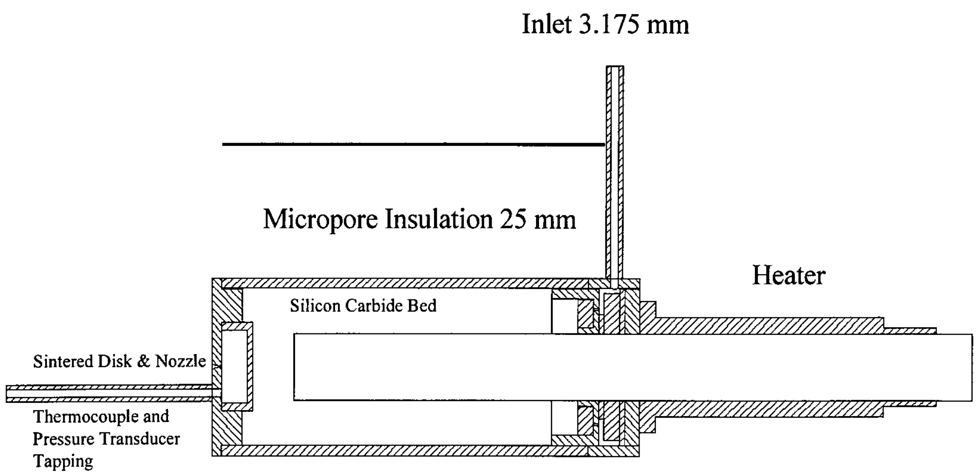


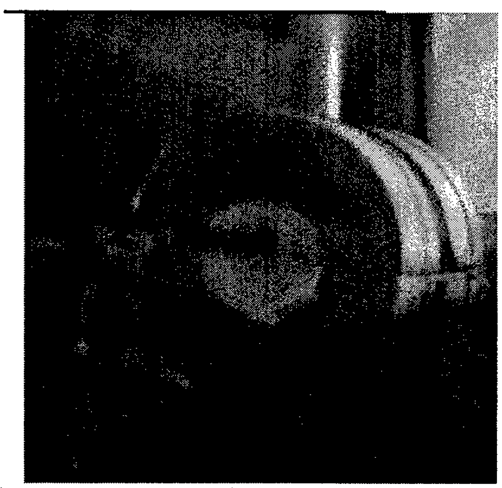
III MARK-II TEST PROGRAMME

The Mark-II was designed to improve on the problems encountered with the Mark-I. It had the following design improvements:

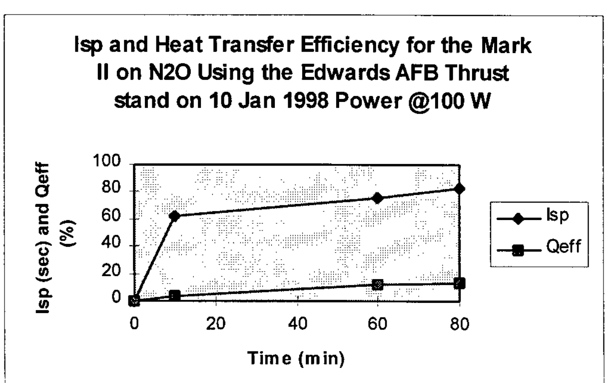
1. Improved heater: longer life and higher temperature (980 C) @ 200 W
2. Improved heat transfer efficiency: chamber dimensions decreased to 30 mm by 90 mm and added 25 mm of Micropore Insulation (SiO_2) to reduce conduction losses.
3. Reduced instrumentation: 2 thermocouples (heater temperature and chamber temperature), and 2 pressure transducers (inlet and chamber) since previous instrumentation caused leaks and additional heat transfer losses
4. welded fittings
5. Nozzle throat diameter: 0.12 mm

A picture of the Mark-II is shown below.



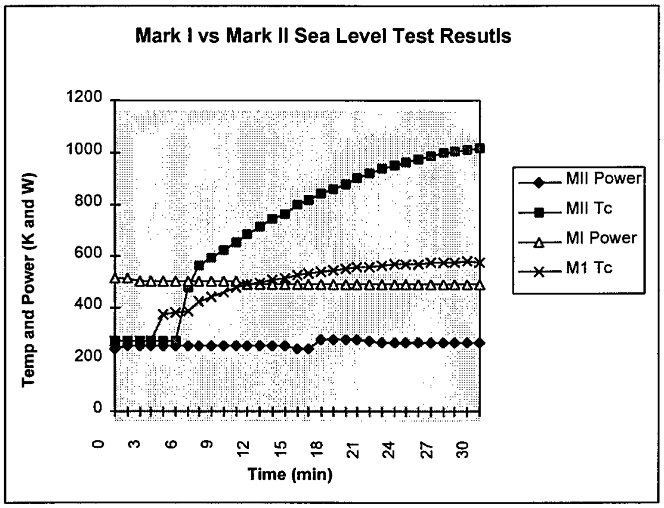


The Mark-II was tested at RO Wescott and at Edwards AFB using the AFRL Electric Propulsion Laboratory's inverted pendulum thrust stand (NASA Lewis design). The results achieved are shown below.



The Mark-II results were slightly better than the Mark-I:

1. Heater lifetime: up to 150 hours without a failure (compared to several hours with the Mark-I heater)
2. Thrust chamber temperature / power requirement. See figure below
3. Micropore insulation reduced radiation losses
4. Faster start-up (less time required to reach steady state)
5. No variation in performance with respect to gravity

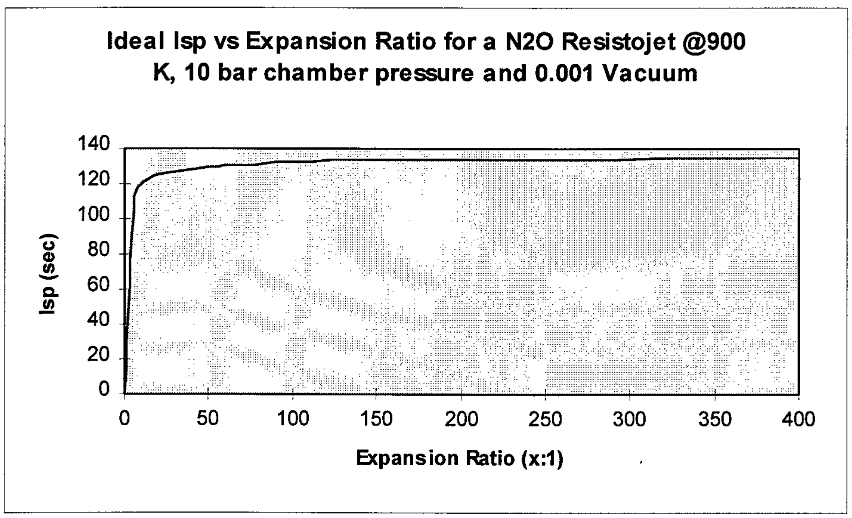


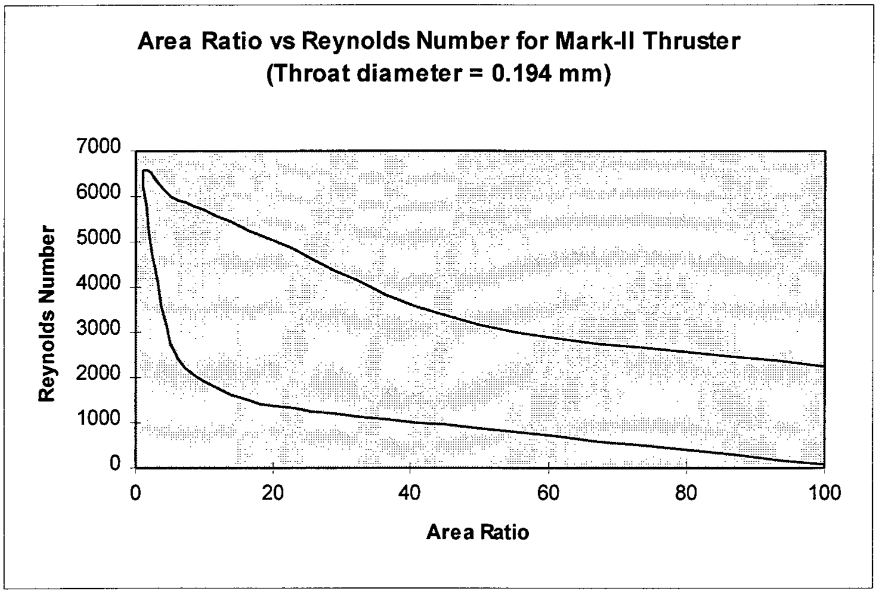
However, the efficiency that was not discovered until we put the thruster on the thrust stand was the friction losses in the nozzle for the low flow rates. Since our flow rates were on the order of 10^{-6} kg/s, friction losses became dominant. This was due to the viscosity of n20 and the small nozzle throat size (0.12 mm throat). It did not matter how much power we put into the gas, the resulting increase in Tc was absorbed by friction losses in the throat. The heat transfer efficiency only reached 12 % with an Isp of 84 sec (Mark-I sea level Isp was 78 sec). Thus, what we thought was increased performance due to higher Tc was lost in the nozzle.

We conducted a study on the physics behind the nozzle friction losses. The Table below shows the varying performance for three of the Mark-II thrusters (there were a total of 5). The performance calculated and measured was for N2O at an approximate chamber pressure of 10 bar and temperature of 900 K . The ratio of Isp's, thrust coefficient, and discharge coefficient all revealed efficiencies between 44 - 67 %. Even though we were putting allot of energy into the gas (high temperatures), the energy was lost in the nozzle.

The figure below shows the ideal Isp as a function of expansion ratio for these similar conditions.

Nozzle throat (mm)	Exp. Ratio	Ideal Isp (sec)	Actual Isp (sec)	% of Ideal Isp	C_D * Particulate could exist in nozzle If less then 1, boundary layers are present	C_F	C_F Ideal
0.12	100:1	131	70	53	.73	.83	1.8
0.128	100:1	131	83	64	.77	1.03	1.8
0.183	100:1	135	101	75	.62	.88	1.8
0.194	100:1	139	99	72	.67	.95	1.8





A Reynolds number analysis was also investigated. According to *Fluid Mechanics* [White, 1986] Reynolds numbers in the few 1000's show the flow is dominated by viscous effects or boundary layers. As the fist plot show, due to the small throat size having an expansion ratio over 10 does not gain that much Isp. As the second plot shows, the Reynolds number drops as we continue to expand through the nozzle. The Reynolds number equals:

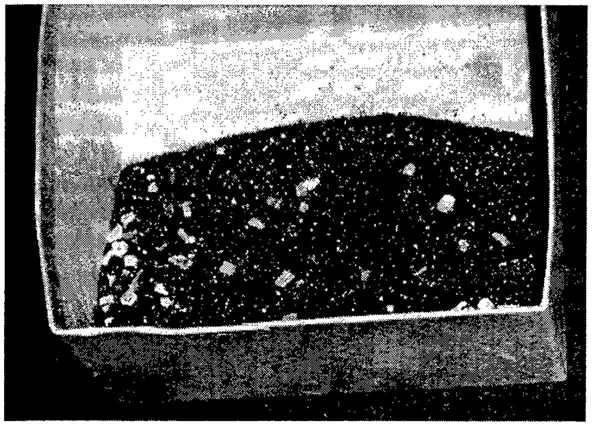
$Re = \rho Ud/V$

where:

ρ = gas density (kg/m^3)
U = local velocity (m/s)
d = local diameter (m)
V= gas viscosity (kg/ms).

Even though the gas velocity and diameter is increasing as we increase the area, they are not enough to compensate for the change in density. The gas viscosity decreases by a factor of 3 compared to a factor of 200 change in density. The Reynolds number analysis thus shows that the boundary layer effects are becoming worse due to our expansion. These results clearly show a bigger nozzle is needed for better performance.

As discussed earlier, there were several thrusters used in the Mark-II programme. One used a mixture of the silicon carbide bed material and magnesium oxide crystals. It was suggested that magnesium oxide could act as a catalyst and allow decomposition to start at 400 C instead of 600 C. This material is shown below:



It would have been ideal to find a 350 um powder of MgO. Unfortunately this was found to be cost prohibitive. The thermodynamic properties of MgO also show it is a very good insulator, so a complete bed composed of it would have caused heat transfer problems. Thus, we decided to make a homogeneous mixture of it as shown in the picture above. Unfortunately, the catalyst material did not work. It actually performed worse than the silicon carbide. We deduced that any added decomposition that was gained from lower decomposition at lower temperature was lost due to the poor heat transfer characteristics of MgO. This is evidenced in the above table. The 4th thruster used the MgO catalyst. Even though it's friction losses were slightly less, its Isp was lower.

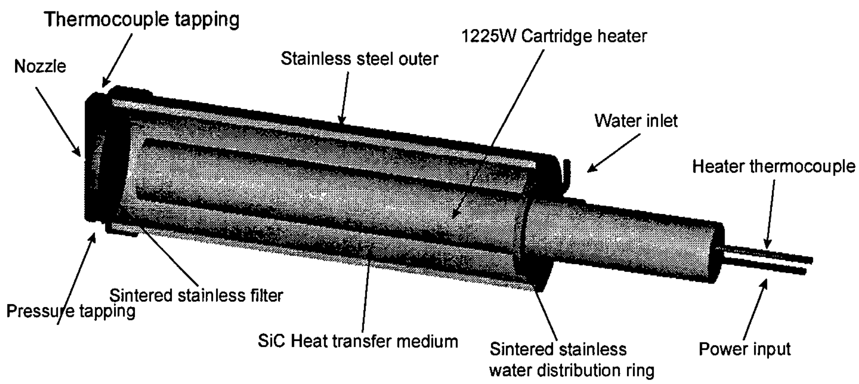
We never reached 100% heat transfer efficiency which was observed in the Mark-I or had any decomposition. Chamber temperature immediately dropped once the power was cut off. We deduced that we needed to build a bigger thruster (higher mass flow and throat size) and incorporate some of the design features of the Mark-II: hence the Mark-III.

IV. MARK-III TEST PROGRAMME

The Mark-III is shown below. It is a bigger system:

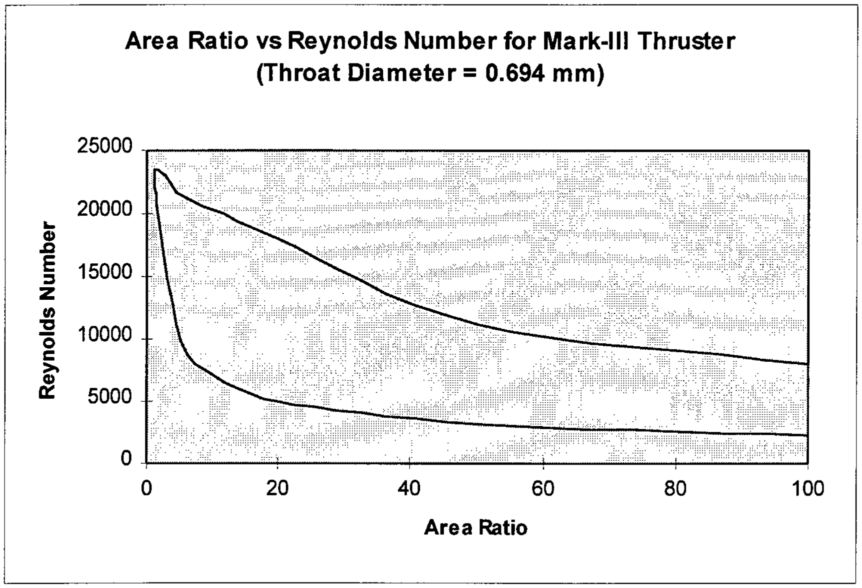
1. 60 mm x 220 mm chamber
2. 0 - 600 W heater
3. flowrate: 0.0004 kg/s @ 10 bar
4. Nozzle throat: 0.7 mm diameter
5. 25 mm thick Micropore insulation
6. welded fittings
7. reduced instrumentation (have thrust stand)

Cutaway of Mark- III Resistojet

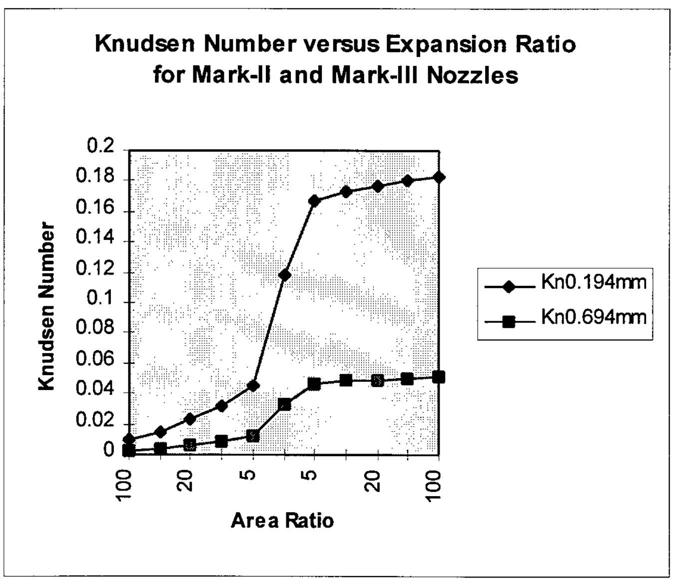


The thruster used the standard 350 um silicon carbide bed material.

The table below shows that the results with the bigger thruster were much improved then the Mark-II programme. The Isp ratio and thrust coefficient were 96 - 97 %. The discharge coefficient and Reynolds number analysis show boundary layers were not as much of a factor (see plot below). The Reynolds Number remains high throughout the expansion. The last plot shows a comparison of the Knudsen number for the Mark-II and Mark-III thrusters. The Knudsen number is the ratio of the mean free path of molecular collisions to the geometric diameter. If this number is significantly less then 1, then the continuum flow calculations can be used. If it gets greater then 0.01, then the flow starts to breaks down. As the figure shows, this was a problem in the Mark-II thruster. The flow is breaking down as we expand (increasing Knudsen) number. This also tells us we are probably developing shocks in the nozzle as the flow breaks down, adding to the boundary layer losses. As the Mark-III nozzle shows, this was not as much a problem in that programme.



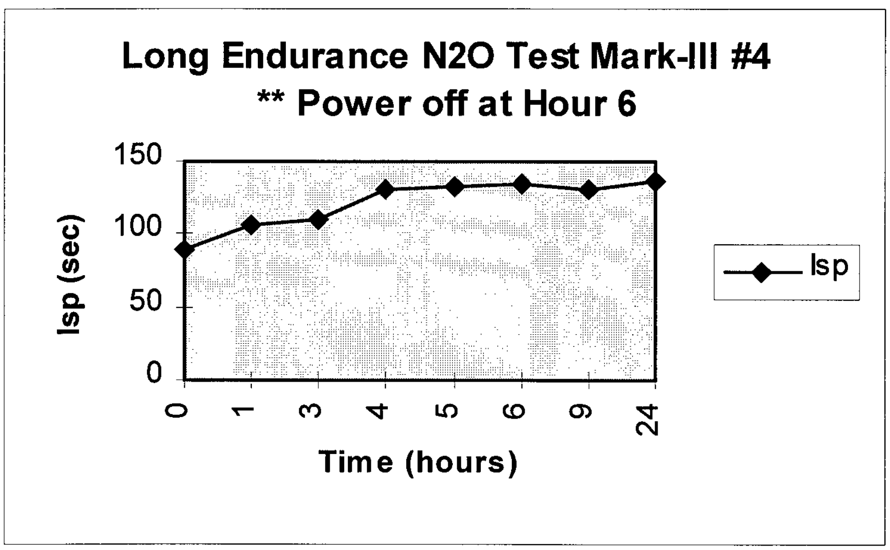
Nozzle throat (mm)	Exp. Ratio	Ideal Isp (sec)	Actual Isp (sec)	% of Ideal Isp	C_D	C_F	C_F Ideal
0.694	100:1	140	134	96	.87	1.76	1.82

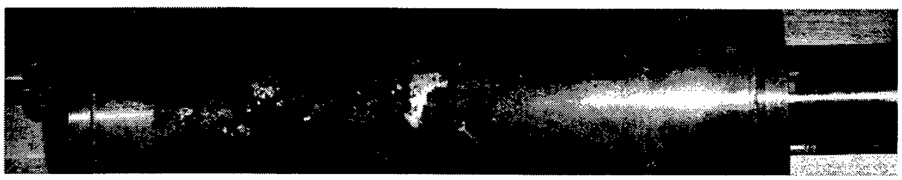


The better performing nozzle and heat transfer performance lead to interesting results with the Mark-III. As the figure below shows, we were able to run the resistojet with no power for 18 hours. We attribute this first known sustained nitrous oxide decomposition in a resistojet due to the high heat transfer efficiency of the mark-III. It was on the order of 75 % steady state (factor of 2 higher than Mark-I and 15 higher than the Mark-II). We might have come close to doing this in the Mark- I (heat transfer efficiency over 100 %

for a period of time (better then the Mark-II), but the poor conduction losses allowed the reaction to shut down when we turned off the power).

We did observe in one of the tests (shown below) a rapid increase in temperature and then a gradual decay to about 800 C (from 1000C). Since the full decomposition occurs at 1600 C, the reaction initially went to full decomposition, but heat transfer and flow losses brought the temperature back down to 800 C. No changes were made to the flow during the entire time (let it run over night). The slight decrease in thrust and performance was due to the reduced mass flow as the n20 cylinder gradually became fully expelled. This reaction has interesting impact for resistojet design. The high storage density of nitrous oxide (400 - 700 kg /m^3) allow for a good density Isp (75 sec). The ability to run the reaction without power for long periods of time also is good since power is a tight commodity on small satellites. The two photographs shown below show the thruster as the reaction was occurring - glowed a bright orange/white. The thruster did discolour to a dark brown on the outer wall which is also evidence of the high temperatures reached.





V CONCLUSIONS / FUTURE WORK

We were very pleased with the results obtained in this test programme (over 60 hours of data generated). We feel we have demonstrated with the Mark-III the first ever re-startable self-sustaining nitrous oxide resistojet. We also feel we have the first well documented friction flow losses in small nozzle using nitrous oxide as the propellant. As spacecraft become smaller and smaller, lower power options are being investigated (especially with MEMS technology). This research shows that friction losses are an important consideration in the design of these systems. Our last conclusion is that the resistojet looks promising as a possible starting mechanism for a hybrid (especially with the decomposition reaction occurring). The results show that it does take 10 - 15 minutes to reach steady state which would be a limiting factor for hybrid application. However, the bed cold be heated at lower power for a longer time allowing the bed to reach a certain temperature. Once this temperature is reached the flow could be brought on and the reaction would be self-sustaining. This is how we originally got the reaction to go, we turned off the flow and power to set our thrust measurement to zero (were experiencing a little bit of thermal drift +- 3 mN). When we turned the flow on, we then observed the reaction. This and further research is needed in the following areas:

1. Is heat transfer efficiency the driving factor in the self-sustaining decomposition ?
2. Bed temperature, mass flow, and pressure should be measured to see if they are contributing factors to the self-sustaining reaction. They should be varied along with bed temperature with no flow. This would drive us back to something like the Mark-I, but with orbital welding, we think this would not

lead to as many problems (leaks) associated with the screwed fittings in that programme.

3. Hybrid options needed to be addressed. We are still two orders of a magnitude lower in the desired hybrid flow rate. Could a smaller system be used to start up a 400 N motor ?

The University of Surrey will continue to address these issues in its internal hybrid and resistojet programmes. It is planned to fly a nitrous oxide resistojet on UoSat-12. We hope to demonstrate the self-sustaining reaction in space.

Acknowledgments

The author would like to acknowledge Major Jerry Sellers of the European Office of Aerospace Research and Defense and Dr Ron Humble of the United States Air Force Academy for sponsoring and supporting this work.

A special thanks goes to the Air Force Research Laboratory Electric Propulsion Laboratory for free use of their facilities and thrust stand.

I would also like to thank Royal Ordinance Rocket Motors Division for use of their facilities.

Appendix (All Experimental Results)

N2O Resistojet Test #1

Note: Tested at RO Wescott on 12/3/97. Nice spring day, 12 C.
First test using N20. Used gaseous cylinder provided from Kingston Medical Gases - 32 kg.
Have regulator for 10 bar. Using old Hedin heater with SiC bed - only had to change bed material, could keep heater attached. We forgot to put the thermocouples in before we packed the bed, so had to drill them in. No Pi gauge. Just Pc and Pe - before and after the screen mesh right before the nozzle. Turned on heater, no readings. Discovered the wires on the cold end were fried, we cut off the cold end and were able to recrimp the wires into the heater.
Turned on power and tried to get stable readings. Experienced heater problems from the get go.
Amperage started to drop. Dropped to 28 V and 5 amps. we waited awhile for the Tc to reach steady state.

Power	Pc bar	Tc C	Te C	Tstream C	mdot (g/s)	
140	3.8	361			0.25	
140	2.8	200	100	140	0.25	good flow meter, nice and steady
140	2.9	197		140	0.25	

This process took about 20 minutes, we then ramped up the power. The power supply read 40 V and 7 Amp for a few seconds and then went to zero. we lost the heater.

Waited 1 hour for the apparatus to cool down, and then decided to assemble a new heater.

N2O Test 26/3/97

Note: 26/3/97 0845 Going for reassembled Mark-I thruster with Hedin heater. Lower power for longer life. Cold day today. Tambient = 9 C.
Tc closer to wall than heater.

Time	Power	Massflow	Pi	Pc	Tc	Te	Ts	Te K
0	0	0.25	8.5	2.2	9			
1	0	0.25	9	2.4	9			
2	300	0.25	9	2.4	9			
3	300	0.25	9	2.5	51			
4	300	0.25	9	2.6	122			
5	300	0.25	9.5	2.7	159			
6	300	0.25	9.5	2.8	202			
7	300	0.24	9.5	2.8	237			
8	300	0.24	9.5	2.9	260		99	
9	300	0.24	9.5	3	279		115	
10	300	0.24	9.5	3	297			
11	300	0.24	9.5	3	313	140		413.16
12	300	0.23	9.5	3	326			
13	300	0.22	9.5	3	339			
14	300	0.22	9.5	3	346		140	
15	300	0.22	9.5	3	357			
16	300	0.21	9.5	3	364			

17	300	0.21	9.5	3	371				
18	300	0.21	9.5	3	377				
19	300	0.21	9.5	3	383				
20	300	0.2	9.5	3	387				
21	300	0.2	9.5	3	390				
22	300	0.2	9.5	3	394				
23	300	0.2	9.5	3	398		195		
24	300	0.2	9.5	3	401	221		494.16	
25	300	0.2	9.5	3	404				
26	315	0.2	9.5	3	405				
27	315	0.2	9.5	3	408				
28	315	0.2	9.5	3	410				
29	315	0.2	9.5	3	411				
30	315	0.2	9.5	3	412				
31	315	0.2	9.5	3	413				
32	315	0.2	9.5	3	414				
33	315	0.2	9.5	3.1	415				
34	315	0.2	9.5	3.1	416				adding insulator hybrid strip
35	315	0.2	9.5	3.1	417				big strip lossley around rig
36	315	0.2	9.5	3.1	417				and t-shirt keep wind off
37	315	0.2	9.5	3.1	417				
38	315	0.2	9.5	3.2	417				
39	315	0.25	10.9	3.9	414				increased regulator Pi
40	315	0.25	10.9	4	410				
41	315	0.25	10.9	4	406				
42	532	0.25	10.9	4	421				increasing power
43	532	0.25	10.9	4	459				
44	532	0.25	10.9	3.9	499				
45	494	0.25	10.9	3.9	548				moving on its own
46	418	0.25	10.9	3.9	581				
47	532	0.25	10.9	3.9	601				power off brieflty, power on
									Tc dropped suddenly
									v, a all over place
									fiffled with power control
									lost heater
									shut off at 48:30

Time	Power	massflow	Cp	Ti	Tf	Pc	C*(Tc)	C* (Te)	C*
2	300	0.25	892	282.16	282.16	240000	345.80369		188.16
3	300	0.25	892	282.16	324.16	250000	370.64795		196
4	300	0.25	892	282.16	395.16	260000	409.23087		203.84
5	300	0.25	892	282.16	432.16	270000	427.96098		211.68
6	300	0.25	892	282.16	475.16	280000	448.74728		219.52
7	300	0.24	892	282.16	510.16	280000	464.98088		228.66667
8	300	0.24	892	282.16	533.16	290000	475.34691		236.83333
9	300	0.24	892	282.16	552.16	300000	483.74263		245
10	300	0.24	892	282.16	570.16	300000	491.56422		245
11	300	0.24	892	282.16	586.16	300000	498.41371	418.44755	245
12	300	0.23	892	282.16	599.16	300000	503.91038		255.65217
13	300	0.22	892	282.16	612.16	300000	509.34772		267.27273

14	300	0.22	892	282.16	619.16	300000	512.25162		267.27273
15	300	0.22	892	282.16	630.16	300000	516.78192		267.27273
16	300	0.21	892	282.16	637.16	300000	519.64427		280
17	300	0.21	892	282.16	644.16	300000	522.49095		280
18	300	0.21	892	282.16	650.16	300000	524.91867		280
19	300	0.21	892	282.16	656.16	300000	527.33521		280
20	300	0.2	892	282.16	660.16	300000	528.94011		294
21	300	0.2	892	282.16	663.16	300000	530.14059		294
22	300	0.2	892	282.16	667.16	300000	531.73702		294
23	300	0.2	892	282.16	671.16	300000	533.32867		294
24	300	0.2	892	282.16	674.16	300000	534.51929	457.63127	294
25	300	0.2	892	282.16	677.16	300000	535.70727		294
26	315	0.2	892	282.16	678.16	300000	536.10268		294
27	315	0.2	892	282.16	681.16	300000	537.28716		294
28	315	0.2	892	282.16	683.16	300000	538.07537		294
29	315	0.2	892	282.16	684.16	300000	538.46903		294
30	315	0.2	892	282.16	685.16	300000	538.86242		294
31	315	0.2	892	282.16	686.16	300000	539.25551		294
32	315	0.2	892	282.16	687.16	300000	539.64832		294
33	315	0.2	892	282.16	688.16	310000	540.04084		303.8
34	315	0.2	892	282.16	689.16	310000	540.43308		303.8
35	315	0.2	892	282.16	690.16	310000	540.82503		303.8
36	315	0.2	892	282.16	690.16	310000	540.82503		303.8
37	315	0.2	892	282.16	690.16	310000	540.82503		303.8
38	315	0.2	892	282.16	690.16	320000	540.82503		313.6
39	315	0.25	892	282.16	687.16	390000	539.64832		305.76
40	315	0.25	892	282.16	683.16	400000	538.07537		313.6
41	315	0.25	892	282.16	679.16	400000	536.4978		313.6
42	532	0.25	892	282.16	694.16	400000	542.39002		313.6
43	532	0.25	892	282.16	732.16	400000	557.03809		313.6
44	532	0.25	892	282.16	772.16	390000	572.05205		305.76
45	494	0.25	892	282.16	821.16	390000	589.92362		305.76
46	418	0.25	892	282.16	854.16	390000	601.66051		305.76
47	532	0.25	892	282.16	874.16	390000	608.66364		305.76

Thrust based upon mdot and Ve, Isp ve and C*

Time	Q eff	C* Tc eff	C* Te eff	Q eff Te	Ve	Isp Ve	F	Isp C*	dropped last tt
2	0	54.412376							
3	3.122	52.880368							
4	8.3996667	49.810515							
5	11.15	49.462453							
6	14.346333	48.918402							
7	16.27008	49.177649							
8	17.91136	49.823262							
9	19.2672	50.646766							
10	20.55168	49.840893							
11	21.69344	49.155951	58.549751	9.34816	387.06224	39.455886	0.0928949	22.66344	
12	21.678573	50.73366							
13	21.5864	52.47353							
14	22.044293	52.176063							

15	22.76384	51.718668						
16	22.1662	53.883015						
17	22.60328	53.589445						
18	22.97792	53.341597						
19	23.35256	53.097156						
20	22.4784	55.582853						
21	22.6568	55.456988						
22	22.894667	55.29049						
23	23.132533	55.125482						
24	23.310933	55.002692	64.243862	12.606933	423.30701	43.150562	0.0846614	27.196129
25	23.489333	54.880718						
26	22.427429	54.840241						
27	22.597333	54.719342						
28	22.710603	54.639186						
29	22.767238	54.59924						
30	22.823873	54.559381						
31	22.880508	54.51961						
32	22.937143	54.479925						
33	22.993778	56.255004						
34	23.050413	56.214175						
35	23.107048	56.173435						
36	23.107048	56.173435						
37	23.107048	56.173435						
38	23.107048	57.985481						
39	28.671429	56.659122						
40	28.388254	58.281798						
41	28.105079	58.453176						
42	17.269925	57.818173						
43	18.862782	56.297766						
44	20.539474	53.449682						
45	24.331377	51.830438						
46	30.515789	50.819356						
47	24.815038	50.234642						

N_2O Resistojet Test 30/3/97

Note: Modified rig. Still went with new heater. Malcolm took a coil (d=1/8")
and length = 500 mm) and curled in front of nozzle and wrapped at back end of
thrust chamber for inlet gas. Then wrapped entire rig in insulation fibre glass tape with fire blanket. Loose wrap.
Tambient = 9 C.

Time	Power	Flow	Pi	Pc	Th	Tc	Te
0	260	0	0	0	9	0	0
1	247	0	0	0	521	0	0
2	247	0.25	2.6	2.5	802	247	14
3	247	0.25	2.7	2.7	879	299	26
4	247	0.25	3	2.9	940	331	44

5	247	0.25	3	3.1	971	370	64
6	247	0.25	3.2	3.25	1007	397	87
7	247	0.25	3.5	3.45	1024	426	108
8	247	0.25	3.5	3.6	1040	440	124
9	247	0.25	3.7	3.7	1047	465	146
10	247	0.25	3.8	3.8	1059	473	157
11	247	0.25	3.9	3.9	1066	490	175
12	247	0.25	4	4	1074	498	187
13	247	0.25	4	4.1	1081	515	205
14	247	0.25	4.1	4.2	1087	522	216
15	247	0.25	4.2	4.2	1094	536	230
16	247	0.25	4.3	4.3	1103	547	245
17	247	0.25	4.4	4.4	1106	556	255
18	247	0.25	4.5	4.5	1112	563	264
19	247	0.245	4.5	4.5	1117	572	272
20	247	0.25	4.6	4.7	1124	579	282
21	247	0.25	4.7	4.75	1126	589	292
22	247	0.25	4.75	4.8	1126	595	299
23	247	0.25	4.8	4.8	1126	603	306
24	247	0.25	4.9	4.9	1125	609	313
25	247	0.25	4.9	4.95	1125	619	320
26	247	0.25	5	5	1125	624	326
27	247	0.25	5	5	1126	632	331
28	247	0.25	5	5.05	1128	638	337
29	247	0.25	5	5.1	1129	647	342
30	247	0.25	5	5.1	1129	652	347
31	247	0.25	5.1	5.2	1129	659	351
32	247	0.25	5.1	5.2	1129	667	356
33	247	0.25	5.1	5.2	1129	672	361
34	247	0.25	5.1	5.2	1129	681	366
35	247	0.25	5	5.2	1129	687	371
36	247	0.25	5	5.2	1129	693	375
37	247	0.25	5	5.2	1129	697	378
38	247	0.25	5	5.2	1129	704	382
39	247	0.25	5	5.25	1129	707	386
40	247	0.25	5	5.25	1129	713	389
41	247	0.25	5	5.25	1129	717	394
42	247	0.25	5	5.25	1129	723	398
43	247	0.25	5	5.25	1129	724	399
44	247	0.25	5	5.25	1129	730	402
45	247	0.25	5	5.25	1129	734	405
46	247	0.25	5	5.25	1129	738	409
47	247	0.25	5	5.25	1129	743	413
48	247	0.25	5	5.25	1129	748	416
49	247	0.25	5	5.25	1129	751	419
50	247	0.25	5	5.25	1129	754	422
51	247	0.25	5	5.25	1129	760	426
52	247	0.25	5	5.2	1129	761	427
53	247	0.25	5	5.2	1129	765	430

54	247	0.25	5	5.2	1129	768	432
55	247	0.25	5	5.15	1129	771	435
56	247	0.25	5	5.15	1129	774	437
57	247	0.25	5	5.1	1129	777	438
58	247	0.25	5	5.1	1129	778	437
59	247	0.25	5	5.1	1129	780	436 flow up
60	247	0.25	5	5.1	1129	781	435
61	247	0.3	6	6.5	1129	791	439
62	247	0.3	6.5	6.5	1129	798	445
63	247	0.3	6.5	6.5	1129	800	448
64	247	0.3	6.5	6.5	1129	800	450
65	247	0.3	6.5	6.5	1129	801	452
66	247	0.3	6.5	6.5	1129	801	454
67	247	0.3	6.5	6.5	1129	801	456
68	247	0.3	6.5	6.5	1129	802	459
69	247	0.3	6.5	6.5	1129	802	460
70	247	0.3	6.5	6.5	1129	803	461
71	247	0.3	6.5	6.5	1129	803	462
72	247	0.3	6.5	6.5	1129	804	463
73	247	0.3	6.5	6.5	1129	804	464
74	247	0.3	6.5	6.5	1129	804	465 flow up
75	247	0.3	6.5	6.5	1129	805	465
76	247	0.35	7.5	7.5	1129	811	468
77	247	0.35	7.5	7.5	1129	819	472
78	247	0.35	7.5	7.5	1129	820	474
79	247	0.35	7.5	7.5	1129	818	474
80	247	0.35	7.5	7.5	1129	816	476
81	247	0.35	7.5	7.5	1129	812	476 flow down
82	247	0.3	6.5	6.5	1129	804	475
83	247	0.3	6.5	6.5	1129	797	473
84	247	0.3	6.5	6.5	1129	794	472
85	247	0.3	6.5	6.5	1129	794	472
86	247	0.3	6.5	6.5	1129	793	471
87	247	0.3	6.5	6.5	1129	793	471
88	247	0.3	6.5	6.5	1129	792	471
89	247	0.3	6.5	6.5	1129	791	470 flow down
90	247	0.25	5	5.1	1129	784	465
91	247	0.25	5	5.1	1129	777	462
92	247	0.25	5	5.1	1129	777	462
93	247	0.25	5	5.1	1129	779	461
94	247	0.25	5	5.1	1129	781	462
95	247	0.25	5	5.1	1129	783	462
100	247	0.25	5	5.1	1129	797	466
105	247	0.25	5	5.1	1129	807	472
110	247	0.25	5	5.1	1129	817	477
115	247	0.25	5	5.1	1130	828	483
120	247	0.25	5	5.1	1130	839	491
125	247	0.25	5	5.1	1130	848	499
130	247	0.25	5	5.2	1129	857	505

135	247	0.25	5	5.2	1130	863	509	
137	247	0.25	5	5.2	1130	873	0	heater fluctuating
140	0	0.25	5	5	845	730	501	power at 200 at 138
145	0	0.25	4.6	4.6	407	411	421	

Took wrapping off. more dark color on chamber silcoset very white and brittle. Burned on silcoset looks salty

no flow temps

Time	Tc	Th	Te	
02:40	227	276	204	
02:45	177	205	161	
02:50	137	159	126	
03:00	85	101	81	

Time	Power	Tf	Ti	Cp	Q calc	Q h calc	C*	C* Tc	C* Te
2	247	520.16	282.16	892	53.074	176.839	196	469.51597	348.85413
3	247	572.16	282.16	892	64.67	194.01	211.68	492.42562	356.06858
4	247	604.16	282.16	892	71.806	207.613	227.36	506.00858	366.62417
5	247	643.16	282.16	892	80.503	214.526	243.04	522.08523	378.00706
6	247	670.16	282.16	892	86.524	222.554	254.8	532.9312	390.6876
7	247	699.16	282.16	892	92.991	226.345	270.48	544.33991	401.91624
8	247	713.16	282.16	892	96.113	229.913	282.24	549.76284	410.26517
9	247	738.16	282.16	892	101.688	231.474	290.08	559.31588	421.47499
10	247	746.16	282.16	892	103.472	234.15	297.92	562.33857	426.96955
11	247	763.16	282.16	892	107.263	235.711	305.76	568.70847	435.81125
12	247	771.16	282.16	892	109.047	237.495	313.6	571.6815	441.60738
13	247	788.16	282.16	892	112.838	239.056	321.44	577.94843	450.16167
14	247	795.16	282.16	892	114.399	240.394	329.28	580.50927	455.31018
15	247	809.16	282.16	892	117.521	241.955	329.28	585.59734	461.77982
16	247	820.16	282.16	892	119.974	243.962	337.12	589.56431	468.61246
17	247	829.16	282.16	892	121.981	244.631	344.96	592.79027	473.11275
18	247	836.16	282.16	892	123.542	245.969	352.8	595.28726	477.12671
19	247	845.16	282.16	892	123.03802	242.14232	360	598.48237	480.66653
20	247	852.16	282.16	892	127.11	248.645	368.48	600.95571	485.05499
21	247	862.16	282.16	892	129.34	249.091	372.4	604.4715	489.4041
22	247	868.16	282.16	892	130.678	249.091	376.32	606.57119	492.42562
23	247	876.16	282.16	892	132.462	249.091	376.32	609.35953	495.42871
24	247	882.16	282.16	892	133.8	248.868	384.16	611.44243	498.41371
25	247	892.16	282.16	892	136.03	248.868	388.08	614.89827	501.38094
26	247	897.16	282.16	892	137.145	248.868	392	616.61892	503.91038
27	247	905.16	282.16	892	138.929	249.091	392	619.36202	506.00858
28	247	911.16	282.16	892	140.267	249.537	395.92	621.4114	508.51499
29	247	920.16	282.16	892	142.274	249.76	399.84	624.47286	510.59427
30	247	925.16	282.16	892	143.389	249.76	399.84	626.1672	512.66512
31	247	932.16	282.16	892	144.95	249.76	407.68	628.53161	514.31579
32	247	940.16	282.16	892	146.734	249.76	407.68	631.22295	516.37172
33	247	945.16	282.16	892	147.849	249.76	407.68	632.89922	518.41949
34	247	954.16	282.16	892	149.856	249.76	407.68	635.90538	520.4592
35	247	960.16	282.16	892	151.194	249.76	407.68	637.90161	522.49095

36	247	966.16	282.16	892	152.532	249.76	407.68	639.89162	524.11068
37	247	970.16	282.16	892	153.424	249.76	407.68	641.21486	525.3222
38	247	977.16	282.16	892	154.985	249.76	407.68	643.52398	526.93322
39	247	980.16	282.16	892	155.654	249.76	411.6	644.51107	528.53934
40	247	986.16	282.16	892	156.992	249.76	411.6	646.48073	529.74073
41	247	990.16	282.16	892	157.884	249.76	411.6	647.79051	531.73702
42	247	996.16	282.16	892	159.222	249.76	411.6	649.75023	533.32867
43	247	997.16	282.16	892	159.445	249.76	411.6	650.07628	533.72584
44	247	1003.16	282.16	892	160.783	249.76	411.6	652.02913	534.91558
45	247	1007.16	282.16	892	161.675	249.76	411.6	653.32779	536.10268
46	247	1011.16	282.16	892	162.567	249.76	411.6	654.62387	537.68141
47	247	1016.16	282.16	892	163.682	249.76	411.6	656.24037	539.25551
48	247	1021.16	282.16	892	164.797	249.76	411.6	657.8529	540.43308
49	247	1024.16	282.16	892	165.466	249.76	411.6	658.81852	541.60809
50	247	1027.16	282.16	892	166.135	249.76	411.6	659.78273	542.78056
51	247	1033.16	282.16	892	167.473	249.76	411.6	661.70693	544.33991
52	247	1034.16	282.16	892	167.696	249.76	407.68	662.02709	544.72906
53	247	1038.16	282.16	892	168.588	249.76	407.68	663.30617	545.89482
54	247	1041.16	282.16	892	169.257	249.76	407.68	664.26387	546.67061
55	247	1044.16	282.16	892	169.926	249.76	403.76	665.22019	547.83224
56	247	1047.16	282.16	892	170.595	249.76	403.76	666.17513	548.6053
57	247	1050.16	282.16	892	171.264	249.76	399.84	667.12871	548.99142
58	247	1051.16	282.16	892	171.487	249.76	399.84	667.44627	548.6053
59	247	1053.16	282.16	892	171.933	249.76	399.84	668.08093	548.21891
60	247	1054.16	282.16	892	172.156	249.76	399.84	668.39803	547.83224
61	247	1064.16	282.16	892	209.2632	299.712	424.66667	671.56083	549.37726
62	247	1071.16	282.16	892	211.1364	299.712	424.66667	673.76596	551.68668
63	247	1073.16	282.16	892	211.6716	299.712	424.66667	674.39468	552.83777
64	247	1073.16	282.16	892	211.6716	299.712	424.66667	674.39468	553.60384
65	247	1074.16	282.16	892	211.9392	299.712	424.66667	674.70881	554.36884
66	247	1074.16	282.16	892	211.9392	299.712	424.66667	674.70881	555.1328
67	247	1074.16	282.16	892	211.9392	299.712	424.66667	674.70881	555.8957
68	247	1075.16	282.16	892	212.2068	299.712	424.66667	675.0228	557.03809
69	247	1075.16	282.16	892	212.2068	299.712	424.66667	675.0228	557.41837
70	247	1076.16	282.16	892	212.4744	299.712	424.66667	675.33665	557.79839
71	247	1076.16	282.16	892	212.4744	299.712	424.66667	675.33665	558.17815
72	247	1077.16	282.16	892	212.742	299.712	424.66667	675.65035	558.55765
73	247	1077.16	282.16	892	212.742	299.712	424.66667	675.65035	558.93689
74	247	1077.16	282.16	892	212.742	299.712	424.66667	675.65035	559.31588
75	247	1078.16	282.16	892	213.0096	299.712	424.66667	675.9639	559.31588
76	247	1084.16	282.16	892	250.3844	349.664	420	677.84217	560.4513
77	247	1092.16	282.16	892	252.882	349.664	420	680.33847	561.96163
78	247	1093.16	282.16	892	253.1942	349.664	420	680.64986	562.71527
79	247	1091.16	282.16	892	252.5698	349.664	420	680.02693	562.71527
80	247	1089.16	282.16	892	251.9454	349.664	420	679.40343	563.46791
81	247	1085.16	282.16	892	250.6966	349.664	420	678.15471	563.46791
82	247	1077.16	282.16	892	212.742	299.712	424.66667	675.65035	563.09171
83	247	1070.16	282.16	892	210.8688	299.712	424.66667	673.45139	562.33857
84	247	1067.16	282.16	892	210.066	299.712	424.66667	672.50677	561.96163

85	247	1067.16	282.16	892	210.066	299.712	424.66667	672.50677	561.96163
86	247	1066.16	282.16	892	209.7984	299.712	424.66667	672.19161	561.58443
87	247	1066.16	282.16	892	209.7984	299.712	424.66667	672.19161	561.58443
88	247	1065.16	282.16	892	209.5308	299.712	424.66667	671.87629	561.58443
89	247	1064.16	282.16	892	209.2632	299.712	424.66667	671.56083	561.20697
90	247	1057.16	282.16	892	172.825	249.76	399.84	669.34844	559.31588
91	247	1050.16	282.16	892	171.264	249.76	399.84	667.12871	558.17815
92	247	1050.16	282.16	892	171.264	249.76	399.84	667.12871	558.17815
93	247	1052.16	282.16	892	171.71	249.76	399.84	667.76367	557.79839
94	247	1054.16	282.16	892	172.156	249.76	399.84	668.39803	558.17815
95	247	1056.16	282.16	892	172.602	249.76	399.84	669.03179	558.17815
100	247	1070.16	282.16	892	175.724	249.76	399.84	673.45139	559.69461
105	247	1080.16	282.16	892	177.954	249.76	399.84	676.59057	561.96163
110	247	1090.16	282.16	892	180.184	249.76	399.84	679.71525	563.84385
115	247	1101.16	282.16	892	182.637	249.983	399.84	683.1359	566.09425
120	247	1112.16	282.16	892	185.09	249.983	399.84	686.5395	569.08095
125	247	1121.16	282.16	892	187.097	249.983	399.84	689.31177	572.05205
130	247	1130.16	282.16	892	189.104	249.76	407.68	692.07293	574.27029
135	247	1136.16	282.16	892	190.442	249.983	407.68	693.9076	575.74436
137	247	1146.16	282.16	892	192.672	249.983	407.68	696.95465	
140	0	1003.16	282.16	892	160.783	186.428	392	652.02913	572.79241
145	0	684.16	282.16	892	89.646	88.754	360.64	538.46903	542.39002

Time	Q eff	C* eff Th	C* eff	Q h eff	Q eff Te	C* eff Te
2	21.487449	29.036056	41.745119	71.594737	0.451417	56.183942
3	26.182186	30.292948	42.987203	78.546559	1.5348178	59.449221
4	29.071255	31.708312	44.932045	84.053846	3.159919	62.014459
5	32.592308	33.470157	46.551786	86.852632	4.965587	64.295095
6	35.02996	34.592775	47.81105	90.102834	7.0421053	65.218348
7	37.648178	36.480139	49.68954	91.637652	8.9380567	67.297604
8	38.912146	37.833616	51.338501	93.082186	10.382591	68.794532
9	41.169231	38.781322	51.863359	93.71417	12.368826	68.824961
10	41.891498	39.649669	52.978759	94.797571	13.361943	69.775467
11	43.426316	40.586588	53.763926	95.429555	14.987045	70.158813
12	44.148583	41.503485	54.855719	96.151822	16.070445	71.013305
13	45.683401	42.430977	55.617419	96.783806	17.695547	71.405457
14	46.315385	43.369904	56.722609	97.325506	18.688664	72.319929
15	47.579352	43.258732	56.229763	97.95749	19.952632	71.306711
16	48.57247	44.143642	57.181209	98.77004	21.306883	71.940041
17	49.38502	45.121083	58.192588	99.040891	22.209717	72.912853
18	50.017004	46.046509	59.265505	99.582591	23.022267	73.942623
19	49.812964	46.90166	60.152148	98.033328	23.269644	74.895999
20	51.461538	47.886043	61.315667	100.66599	24.647368	75.966644
21	52.364372	48.360868	61.607537	100.84656	25.550202	76.092538
22	52.906073	48.86993	62.040533	100.84656	26.182186	76.421694
23	53.62834	48.86993	61.756645	100.84656	26.81417	75.958456
24	54.17004	49.905891	62.828482	100.75628	27.446154	77.076531
25	55.072874	50.415135	63.112879	100.75628	28.078138	77.402224
26	55.524291	50.924378	63.57249	100.75628	28.619838	77.791611

27	56.246559	50.906177	63.290933	100.84656	29.071255	77.469043
28	56.788259	51.378531	63.713025	101.02713	29.612955	77.858078
29	57.60081	51.868723	64.028403	101.11741	30.064372	78.308752
30	58.052227	51.868723	63.855149	101.11741	30.515789	77.992433
31	58.684211	52.885757	64.86229	101.11741	30.876923	79.266475
32	59.406478	52.885757	64.585738	101.11741	31.32834	78.950877
33	59.857895	52.885757	64.414679	101.11741	31.779757	78.639019
34	60.670445	52.885757	64.110167	101.11741	32.231174	78.330828
35	61.212146	52.885757	63.909542	101.11741	32.682591	78.026232
36	61.753846	52.885757	63.710789	101.11741	33.043725	77.785097
37	62.11498	52.885757	63.579313	101.11741	33.314575	77.605706
38	62.746964	52.885757	63.351175	101.11741	33.675709	77.368437
39	63.017814	53.394274	63.862363	101.11741	34.036842	77.874998
40	63.559514	53.394274	63.667791	101.11741	34.307692	77.698387
41	63.920648	53.394274	63.53906	101.11741	34.759109	77.406686
42	64.462348	53.394274	63.347419	101.11741	35.120243	77.175675
43	64.552632	53.394274	63.315647	101.11741	35.210526	77.118245
44	65.094332	53.394274	63.126014	101.11741	35.481377	76.946721
45	65.455466	53.394274	63.000535	101.11741	35.752227	76.776337
46	65.816599	53.394274	62.875801	101.11741	36.11336	76.550908
47	66.268016	53.394274	62.720921	101.11741	36.474494	76.327454
48	66.719433	53.394274	62.567179	101.11741	36.745344	76.161141
49	66.990283	53.394274	62.475475	101.11741	37.016194	75.995911
50	67.261134	53.394274	62.384173	101.11741	37.287045	75.831751
51	67.802834	53.394274	62.202764	101.11741	37.648178	75.614517
52	67.893117	52.885757	61.580561	101.11741	37.738462	74.840876
53	68.254251	52.885757	61.461813	101.11741	38.009312	74.681053
54	68.525101	52.885757	61.373201	101.11741	38.189879	74.575071
55	68.795951	52.37724	60.695693	101.11741	38.460729	73.701394
56	69.066802	52.37724	60.608687	101.11741	38.641296	73.597539
57	69.337652	51.868723	59.934462	101.11741	38.731579	72.83174
58	69.427935	51.868723	59.905946	101.11741	38.641296	72.883
59	69.608502	51.868723	59.849037	101.11741	38.551012	72.934369
60	69.698785	51.868723	59.820643	101.11741	38.460729	72.985846
61	84.721943	55.08933	63.23577	121.34089	46.586235	77.299643
62	85.480324	55.08933	63.02881	121.34089	47.236275	76.976059
63	85.697004	55.08933	62.97005	121.34089	47.561296	76.815783
64	85.697004	55.08933	62.97005	121.34089	47.777976	76.709487
65	85.805344	55.08933	62.940732	121.34089	47.994656	76.603632
66	85.805344	55.08933	62.940732	121.34089	48.211336	76.498213
67	85.805344	55.08933	62.940732	121.34089	48.428016	76.393228
68	85.913684	55.08933	62.911455	121.34089	48.753036	76.236558
69	85.913684	55.08933	62.911455	121.34089	48.861377	76.184548
70	86.022024	55.08933	62.882219	121.34089	48.969717	76.132645
71	86.022024	55.08933	62.882219	121.34089	49.078057	76.080848
72	86.130364	55.08933	62.853023	121.34089	49.186397	76.029156
73	86.130364	55.08933	62.853023	121.34089	49.294737	75.97757
74	86.130364	55.08933	62.853023	121.34089	49.403077	75.926088
75	86.238704	55.08933	62.823868	121.34089	49.403077	75.926088

76	101.3702	54.483953	61.961326	141.56437	58.016113	74.939607
77	102.38138	54.483953	61.733978	141.56437	58.5217	74.738199
78	102.50777	54.483953	61.705735	141.56437	58.774494	74.638102
79	102.25498	54.483953	61.76226	141.56437	58.774494	74.638102
80	102.00219	54.483953	61.81894	141.56437	59.027287	74.538407
81	101.4966	54.483953	61.93277	141.56437	59.027287	74.538407
82	86.130364	55.08933	62.853023	121.34089	50.486478	75.416962
83	85.371984	55.08933	63.058251	121.34089	50.269798	75.517968
84	85.046964	55.08933	63.146824	121.34089	50.161457	75.568624
85	85.046964	55.08933	63.146824	121.34089	50.161457	75.568624
86	84.938623	55.08933	63.176431	121.34089	50.053117	75.619381
87	84.938623	55.08933	63.176431	121.34089	50.053117	75.619381
88	84.830283	55.08933	63.20608	121.34089	50.053117	75.619381
89	84.721943	55.08933	63.23577	121.34089	49.944777	75.670241
90	69.969636	51.868723	59.735704	101.11741	41.169231	71.487332
91	69.337652	51.868723	59.934462	101.11741	40.898381	71.633045
92	69.337652	51.868723	59.934462	101.11741	40.898381	71.633045
93	69.518219	51.868723	59.877471	101.11741	40.808097	71.681814
94	69.698785	51.868723	59.820643	101.11741	40.898381	71.633045
95	69.879352	51.868723	59.763977	101.11741	40.898381	71.633045
100	71.14332	51.868723	59.371769	101.11741	41.259514	71.438959
105	72.046154	51.868723	59.096301	101.11741	41.801215	71.150766
110	72.948988	51.868723	58.824633	101.11741	42.252632	70.913251
115	73.942105	51.850237	58.530082	101.20769	42.794332	70.631348
120	74.935223	51.850237	58.239912	101.20769	43.516599	70.260655
125	75.747773	51.850237	58.005683	101.20769	44.238866	69.895738
130	76.560324	52.885757	58.907087	101.11741	44.780567	70.990962
135	77.102024	52.866908	58.751338	101.20769	45.1417	70.809204
137	78.004858	52.866908	58.494481	101.20769		
140		56.944554	60.120014			68.43666
145		67.171718	66.975068			66.490899

N2O Resistojet Test 30/3/97

Note: Modified rig. Still went with new heater. Malcolm took a coil (d=1/8")
and length = 500 mm) and curled in front of nozzle and wrapped at back end of
thrust chamber for inlet gas. Then wrapped entire rig in insulation fibre glass tape with fire blanket. Loose wrap.
Tambient = 9 C.

Time	Power	Flow	Pi	Pc	Th	Tc	Te
0	260	0	0	0	9	0	0
1	247	0	0	0	521	0	0
2	247	0.25	2.6	2.5	802	247	14
3	247	0.25	2.7	2.7	879	299	26
4	247	0.25	3	2.9	940	331	44
5	247	0.25	3	3.1	971	370	64
6	247	0.25	3.2	3.25	1007	397	87
7	247	0.25	3.5	3.45	1024	426	108

8	247	0.25	3.5	3.6	1040	440	124
9	247	0.25	3.7	3.7	1047	465	146
10	247	0.25	3.8	3.8	1059	473	157
11	247	0.25	3.9	3.9	1066	490	175
12	247	0.25	4	4	1074	498	187
13	247	0.25	4	4.1	1081	515	205
14	247	0.25	4.1	4.2	1087	522	216
15	247	0.25	4.2	4.2	1094	536	230
16	247	0.25	4.3	4.3	1103	547	245
17	247	0.25	4.4	4.4	1106	556	255
18	247	0.25	4.5	4.5	1112	563	264
19	247	0.245	4.5	4.5	1117	572	272
20	247	0.25	4.6	4.7	1124	579	282
21	247	0.25	4.7	4.75	1126	589	292
22	247	0.25	4.75	4.8	1126	595	299
23	247	0.25	4.8	4.8	1126	603	306
24	247	0.25	4.9	4.9	1125	609	313
25	247	0.25	4.9	4.95	1125	619	320
26	247	0.25	5	5	1125	624	326
27	247	0.25	5	5	1126	632	331
28	247	0.25	5	5.05	1128	638	337
29	247	0.25	5	5.1	1129	647	342
30	247	0.25	5	5.1	1129	652	347
31	247	0.25	5.1	5.2	1129	659	351
32	247	0.25	5.1	5.2	1129	667	356
33	247	0.25	5.1	5.2	1129	672	361
34	247	0.25	5.1	5.2	1129	681	366
35	247	0.25	5	5.2	1129	687	371
36	247	0.25	5	5.2	1129	693	375
37	247	0.25	5	5.2	1129	697	378
38	247	0.25	5	5.2	1129	704	382
39	247	0.25	5	5.25	1129	707	386
40	247	0.25	5	5.25	1129	713	389
41	247	0.25	5	5.25	1129	717	394
42	247	0.25	5	5.25	1129	723	398
43	247	0.25	5	5.25	1129	724	399
44	247	0.25	5	5.25	1129	730	402
45	247	0.25	5	5.25	1129	734	405
46	247	0.25	5	5.25	1129	738	409
47	247	0.25	5	5.25	1129	743	413
48	247	0.25	5	5.25	1129	748	416
49	247	0.25	5	5.25	1129	751	419
50	247	0.25	5	5.25	1129	754	422
51	247	0.25	5	5.25	1129	760	426
52	247	0.25	5	5.2	1129	761	427
53	247	0.25	5	5.2	1129	765	430
54	247	0.25	5	5.2	1129	768	432
55	247	0.25	5	5.15	1129	771	435
56	247	0.25	5	5.15	1129	774	437

57	247	0.25	5	5.1	1129	777	438
58	247	0.25	5	5.1	1129	778	437
59	247	0.25	5	5.1	1129	780	436 flow up
60	247	0.25	5	5.1	1129	781	435
61	247	0.3	6	6.5	1129	791	439
62	247	0.3	6.5	6.5	1129	798	445
63	247	0.3	6.5	6.5	1129	800	448
64	247	0.3	6.5	6.5	1129	800	450
65	247	0.3	6.5	6.5	1129	801	452
66	247	0.3	6.5	6.5	1129	801	454
67	247	0.3	6.5	6.5	1129	801	456
68	247	0.3	6.5	6.5	1129	802	459
69	247	0.3	6.5	6.5	1129	802	460
70	247	0.3	6.5	6.5	1129	803	461
71	247	0.3	6.5	6.5	1129	803	462
72	247	0.3	6.5	6.5	1129	804	463
73	247	0.3	6.5	6.5	1129	804	464
74	247	0.3	6.5	6.5	1129	804	465 flow up
75	247	0.3	6.5	6.5	1129	805	465
76	247	0.35	7.5	7.5	1129	811	468
77	247	0.35	7.5	7.5	1129	819	472
78	247	0.35	7.5	7.5	1129	820	474
79	247	0.35	7.5	7.5	1129	818	474
80	247	0.35	7.5	7.5	1129	816	476
81	247	0.35	7.5	7.5	1129	812	476 flow down
82	247	0.3	6.5	6.5	1129	804	475
83	247	0.3	6.5	6.5	1129	797	473
84	247	0.3	6.5	6.5	1129	794	472
85	247	0.3	6.5	6.5	1129	794	472
86	247	0.3	6.5	6.5	1129	793	471
87	247	0.3	6.5	6.5	1129	793	471
88	247	0.3	6.5	6.5	1129	792	471
89	247	0.3	6.5	6.5	1129	791	470 flow down
90	247	0.25	5	5.1	1129	784	465
91	247	0.25	5	5.1	1129	777	462
92	247	0.25	5	5.1	1129	777	462
93	247	0.25	5	5.1	1129	779	461
94	247	0.25	5	5.1	1129	781	462
95	247	0.25	5	5.1	1129	783	462
100	247	0.25	5	5.1	1129	797	466
105	247	0.25	5	5.1	1129	807	472
110	247	0.25	5	5.1	1129	817	477
115	247	0.25	5	5.1	1130	828	483
120	247	0.25	5	5.1	1130	839	491
125	247	0.25	5	5.1	1130	848	499
130	247	0.25	5	5.2	1129	857	505
135	247	0.25	5	5.2	1130	863	509
137	247	0.25	5	5.2	1130	873	0 heater fluctuating
140	0	0.25	5	5	845	730	501 power at 200 at 138

145	0	0.25	4.6	4.6	407	411	421

Took wrapping off. more dark color on chamber silcoset very white and brittle. Burned on silcoset looks salty

no flow temps

Time	Tc	Th	Te
02:40	227	276	204
02:45	177	205	161
02:50	137	159	126
03:00	85	101	81

Time	Power	Tf	Ti	Cp	Q calc	Q h calc	C*	C* Tc	C* Te
2	247	520.16	282.16	1100	65.45	218.075	196	469.51597	348.85413
3	247	572.16	282.16	1100	79.75	239.25	211.68	492.42562	356.06858
4	247	604.16	282.16	1100	88.55	256.025	227.36	506.00858	366.62417
5	247	643.16	282.16	1100	99.275	264.55	243.04	522.08523	378.00706
6	247	670.16	282.16	1100	106.7	274.45	254.8	532.9312	390.6876
7	247	699.16	282.16	1100	114.675	279.125	270.48	544.33991	401.91624
8	247	713.16	282.16	1100	118.525	283.525	282.24	549.76284	410.26517
9	247	738.16	282.16	1100	125.4	285.45	290.08	559.31588	421.47499
10	247	746.16	282.16	1100	127.6	288.75	297.92	562.33857	426.96955
11	247	763.16	282.16	1100	132.275	290.675	305.76	568.70847	435.81125
12	247	771.16	282.16	1100	134.475	292.875	313.6	571.6815	441.60738
13	247	788.16	282.16	1100	139.15	294.8	321.44	577.94843	450.16167
14	247	795.16	282.16	1100	141.075	296.45	329.28	580.50927	455.31018
15	247	809.16	282.16	1100	144.925	298.375	329.28	585.59734	461.77982
16	247	820.16	282.16	1100	147.95	300.85	337.12	589.56431	468.61246
17	247	829.16	282.16	1100	150.425	301.675	344.96	592.79027	473.11275
18	247	836.16	282.16	1100	152.35	303.325	352.8	595.28726	477.12671
19	247	845.16	282.16	1100	151.7285	298.606	360	598.48237	480.66653
20	247	852.16	282.16	1100	156.75	306.625	368.48	600.95571	485.05499
21	247	862.16	282.16	1100	159.5	307.175	372.4	604.4715	489.4041
22	247	868.16	282.16	1100	161.15	307.175	376.32	606.57119	492.42562
23	247	876.16	282.16	1100	163.35	307.175	376.32	609.35953	495.42871
24	247	882.16	282.16	1100	165	306.9	384.16	611.44243	498.41371
25	247	892.16	282.16	1100	167.75	306.9	388.08	614.89827	501.38094
26	247	897.16	282.16	1100	169.125	306.9	392	616.61892	503.91038
27	247	905.16	282.16	1100	171.325	307.175	392	619.36202	506.00858
28	247	911.16	282.16	1100	172.975	307.725	395.92	621.4114	508.51499
29	247	920.16	282.16	1100	175.45	308	399.84	624.47286	510.59427
30	247	925.16	282.16	1100	176.825	308	399.84	626.1672	512.66512
31	247	932.16	282.16	1100	178.75	308	407.68	628.53161	514.31579
32	247	940.16	282.16	1100	180.95	308	407.68	631.22295	516.37172
33	247	945.16	282.16	1100	182.325	308	407.68	632.89922	518.41949
34	247	954.16	282.16	1100	184.8	308	407.68	635.90538	520.4592
35	247	960.16	282.16	1100	186.45	308	407.68	637.90161	522.49095
36	247	966.16	282.16	1100	188.1	308	407.68	639.89162	524.11068
37	247	970.16	282.16	1100	189.2	308	407.68	641.21486	525.3222
38	247	977.16	282.16	1100	191.125	308	407.68	643.52398	526.93322

39	247	980.16	282.16	1100	191.95	308	411.6	644.51107	528.53934
40	247	986.16	282.16	1100	193.6	308	411.6	646.48073	529.74073
41	247	990.16	282.16	1100	194.7	308	411.6	647.79051	531.73702
42	247	996.16	282.16	1100	196.35	308	411.6	649.75023	533.32867
43	247	997.16	282.16	1100	196.625	308	411.6	650.07628	533.72584
44	247	1003.16	282.16	1100	198.275	308	411.6	652.02913	534.91558
45	247	1007.16	282.16	1100	199.375	308	411.6	653.32779	536.10268
46	247	1011.16	282.16	1100	200.475	308	411.6	654.62387	537.68141
47	247	1016.16	282.16	1100	201.85	308	411.6	656.24037	539.25551
48	247	1021.16	282.16	1100	203.225	308	411.6	657.8529	540.43308
49	247	1024.16	282.16	1100	204.05	308	411.6	658.81852	541.60809
50	247	1027.16	282.16	1100	204.875	308	411.6	659.78273	542.78056
51	247	1033.16	282.16	1100	206.525	308	411.6	661.70693	544.33991
52	247	1034.16	282.16	1100	206.8	308	407.68	662.02709	544.72906
53	247	1038.16	282.16	1100	207.9	308	407.68	663.30617	545.89482
54	247	1041.16	282.16	1100	208.725	308	407.68	664.26387	546.67061
55	247	1044.16	282.16	1100	209.55	308	403.76	665.22019	547.83224
56	247	1047.16	282.16	1100	210.375	308	403.76	666.17513	548.6053
57	247	1050.16	282.16	1100	211.2	308	399.84	667.12871	548.99142
58	247	1051.16	282.16	1100	211.475	308	399.84	667.44627	548.6053
59	247	1053.16	282.16	1100	212.025	308	399.84	668.08093	548.21891
60	247	1054.16	282.16	1100	212.3	308	399.84	668.39803	547.83224
61	247	1064.16	282.16	1100	258.06	369.6	424.66667	671.56083	549.37726
62	247	1071.16	282.16	1100	260.37	369.6	424.66667	673.76596	551.68668
63	247	1073.16	282.16	1100	261.03	369.6	424.66667	674.39468	552.83777
64	247	1073.16	282.16	1100	261.03	369.6	424.66667	674.39468	553.60384
65	247	1074.16	282.16	1100	261.36	369.6	424.66667	674.70881	554.36884
66	247	1074.16	282.16	1100	261.36	369.6	424.66667	674.70881	555.1328
67	247	1074.16	282.16	1100	261.36	369.6	424.66667	674.70881	555.8957
68	247	1075.16	282.16	1100	261.69	369.6	424.66667	675.0228	557.03809
69	247	1075.16	282.16	1100	261.69	369.6	424.66667	675.0228	557.41837
70	247	1076.16	282.16	1100	262.02	369.6	424.66667	675.33665	557.79839
71	247	1076.16	282.16	1100	262.02	369.6	424.66667	675.33665	558.17815
72	247	1077.16	282.16	1100	262.35	369.6	424.66667	675.65035	558.55765
73	247	1077.16	282.16	1100	262.35	369.6	424.66667	675.65035	558.93689
74	247	1077.16	282.16	1100	262.35	369.6	424.66667	675.65035	559.31588
75	247	1078.16	282.16	1100	262.68	369.6	424.66667	675.9639	559.31588
76	247	1084.16	282.16	1100	308.77	431.2	420	677.84217	560.4513
77	247	1092.16	282.16	1100	311.85	431.2	420	680.33847	561.96163
78	247	1093.16	282.16	1100	312.235	431.2	420	680.64986	562.71527
79	247	1091.16	282.16	1100	311.465	431.2	420	680.02693	562.71527
80	247	1089.16	282.16	1100	310.695	431.2	420	679.40343	563.46791
81	247	1085.16	282.16	1100	309.155	431.2	420	678.15471	563.46791
82	247	1077.16	282.16	1100	262.35	369.6	424.66667	675.65035	563.09171
83	247	1070.16	282.16	1100	260.04	369.6	424.66667	673.45139	562.33857
84	247	1067.16	282.16	1100	259.05	369.6	424.66667	672.50677	561.96163
85	247	1067.16	282.16	1100	259.05	369.6	424.66667	672.50677	561.96163
86	247	1066.16	282.16	1100	258.72	369.6	424.66667	672.19161	561.58443
87	247	1066.16	282.16	1100	258.72	369.6	424.66667	672.19161	561.58443

88	247	1065.16	282.16	1100	258.39	369.6	424.66667	671.87629	561.58443
89	247	1064.16	282.16	1100	258.06	369.6	424.66667	671.56083	561.20697
90	247	1057.16	282.16	1100	213.125	308	399.84	669.34844	559.31588
91	247	1050.16	282.16	1100	211.2	308	399.84	667.12871	558.17815
92	247	1050.16	282.16	1100	211.2	308	399.84	667.12871	558.17815
93	247	1052.16	282.16	1100	211.75	308	399.84	667.76367	557.79839
94	247	1054.16	282.16	1100	212.3	308	399.84	668.39803	558.17815
95	247	1056.16	282.16	1100	212.85	308	399.84	669.03179	558.17815
100	247	1070.16	282.16	1100	216.7	308	399.84	673.45139	559.69461
105	247	1080.16	282.16	1100	219.45	308	399.84	676.59057	561.96163
110	247	1090.16	282.16	1100	222.2	308	399.84	679.71525	563.84385
115	247	1101.16	282.16	1100	225.225	308.275	399.84	683.1359	566.09425
120	247	1112.16	282.16	1100	228.25	308.275	399.84	686.5395	569.08095
125	247	1121.16	282.16	1100	230.725	308.275	399.84	689.31177	572.05205
130	247	1130.16	282.16	1100	233.2	308	407.68	692.07293	574.27029
135	247	1136.16	282.16	1100	234.85	308.275	407.68	693.9076	575.74436
137	247	1146.16	282.16	1100	237.6	308.275	407.68	696.95465	
140	0	1003.16	282.16	1100	198.275	229.9	392	652.02913	572.79241
145	0	684.16	282.16	1100	110.55	109.45	360.64	538.46903	542.39002

N2O Resistojet Test #2

Note: Test #2, also conduced at RO Wescott on 12/3/97. T ambient = 12 C.
Tested in the outdoor bay of J4 site. (same as Test #1)
Had to replace heater due to it failed. Went with another Hedin heater since we had plenty on hand. This one had undergone some initial tests of short duration - 20 minutes to compare with the new ISE heater. We took out the sintered disk at the inlet since we felt flow oscillations should not be a problem. Used loads of silcoset and the same SiC from the previous run.

Time	Power	Massflow	Pc	Tc	Te	Tstream
0	468	0.25	0	80		
1	442	0.25	0	158		
2	455	0.25	0	200		
3	455	0.25	0	255		
4	455	0.25	0	301		
5	455	0.25	3	353		
6	455	0.25	3	392		150
7	455	0.25	3.2	422		150
8	455	0.25	3.2	444		200
9	455	0.25	3.2	466	203	205
10	455	0.25	3.6	483	222	
11	455	0.25	3.7	499	240	210
12	455	0.25	3.7	512	251	235
13	455	0.25	3.8	525		
14	486	0.25	4	537		240
15	486	0.25	4	546		255
16	486	0.25	4	554	291	270

17	486	0.25	4.1	562		310
18	486	0.25	4.1	571	306	320
19	486	0.25	4.1	579	314	322
20	486	0.25	4.2	585	322	330
21	486	0.25	4.3	591	329	335
22	486	0.25	4.4	595	334	345
23	486	0.25	4.45	599	338	345
24	486	0.25	4.5	602	341	347
25	486	0.25	4.5	604	344	345
26	486	0.25	4.5	605	346	345

Amps started to drop again, tried to adjust up to 40 V
stayed at 5 amps
went up to 60 V.
Current went up and then died. Tc continued to drop, we could smell burning, so we knew we heater was failing. Tc never raised during heater amp failure process. Went on for 3 minutes. Then went down to 0 (voltage also). Knew heater gone. Rebuild again - try another Hedin heater since we still have them.

Analysis

Time	Power	Mass flow	Tambient	Tc	Qcalc	Pc	C*	C*(T)	Te
5	455	0.00025	285.16	626.16	76.043	300000	235.2	515.13915	
6	455	0.00025	285.16	665.16	84.74	300000	235.2	530.9394	
7	455	0.00025	285.16	695.16	91.43	320000	250.88	542.78056	
8	455	0.00025	285.16	717.16	96.336	320000	250.88	551.30245	
9	455	0.00025	285.16	739.16	101.242	320000	250.88	559.69461	476.16
10	455	0.00025	285.16	756.16	105.033	360000	282.24	566.09425	495.16
11	455	0.00025	285.16	772.16	108.601	370000	290.08	572.05205	513.16
12	455	0.00025	285.16	785.16	111.5	370000	290.08	576.84745	524.16
13	455	0.00025	285.16	798.16	114.399	380000	297.92	581.60332	
14	486	0.00025	285.16	810.16	117.075	400000	313.6	585.95909	
15	486	0.00025	285.16	819.16	119.082	400000	313.6	589.20478	
16	486	0.00025	285.16	827.16	120.866	400000	313.6	592.07491	564.16
17	486	0.00025	285.16	835.16	122.65	410000	321.44	594.93119	
18	486	0.00025	285.16	844.16	124.657	410000	321.44	598.1282	579.16
19	486	0.00025	285.16	852.16	126.441	410000	321.44	600.95571	587.16
20	486	0.00025	285.16	858.16	127.779	420000	329.28	603.06764	595.16
21	486	0.00025	285.16	864.16	129.117	430000	337.12	605.17221	602.16
22	486	0.00025	285.16	868.16	130.009	440000	344.96	606.57119	607.16
23	486	0.00025	285.16	872.16	130.901	445000	348.88	607.96696	611.16
24	486	0.00025	285.16	875.16	131.57	450000	352.8	609.01168	614.16
25	486	0.00025	285.16	877.16	132.016	450000	352.8	609.70717	617.16
26	486	0.00025	285.16	878.16	132.239	450000	352.8	610.05462	619.16

Time	Qeff	C*eff	Q eff Te	C* eff Te
5	16.712747	45.657567		
6	18.624176	44.298841		

7	20.094505	46.221258		
8	21.172747	45.506781		
9	22.250989	44.824445	9.3610989	55.848009
10	23.084176	49.857422	10.292308	61.611799
11	23.868352	50.708673	11.174505	62.202737
12	24.505495	50.287125	11.713626	61.546584
13	25.142637	51.223917		
14	24.089506	53.519095		
15	24.502469	53.22428		
16	24.869547	52.966271	12.801852	64.134692
17	25.236626	54.029778		
18	25.649588	53.740987	13.490123	64.881181
19	26.016667	53.488135	13.857202	64.437665
20	26.291975	54.60084	14.22428	65.564174
21	26.567284	55.706458	14.545473	66.733926
22	26.750823	56.870489	14.774897	68.004127
23	26.934362	57.384698	14.958436	68.551462
24	27.072016	57.929923	15.096091	69.152187
25	27.163786	57.863843	15.233745	68.983909
26	27.209671	57.830887	15.325514	68.872403

N2O Resistojet Test **#3**

Note: Test date 17 Mar 97 at RO Wescott. Nice day. Using brand new
Hedin heter, reassembled the same thruster apparatus (Mark-I) and used the same
bed (had to add a little more). Going for a longer steady state (hopefully) run than Te than Test #2
Nice to find what steady state is, since we were increasing last time.
Tambinet = 12 C

Time	Power	Massflow	Pi	Pc	Tc	Te	Tstream	
0	481	0	0	0	37	noreading	noreading	
1	499.5	0	0	0	133	noreading	noreading	
2	518	0	0	0	209	noreading	noreading	
3	518	0.25	7.8	7.7	285	noreading	noreading	
4	518	0.25	8	7.8	354	noreading	noreading	
5	518	0.25	9.5	9.5	412	noreading	noreading	reading high due to thermo
6	518	0.21	9.5	9.5	455	noreading	noreading	in nozzle - cannot use thes
7	518	0.2	9.5	9.5	482	noreading	noreading	
8	518	0.2	5	4.2	536	noreading	noreading	thermocouple removed
9	518	0.25	4.9	4.2	546	noreading	noreading	
10	518	0.25	4.9	4.2	554	noreading	200	
11	518	0.25	4.9	4.2	561	noreading	250	
12	518	0.25	4.9	4.2	569	noreading	270	
13	504	0.25	4.9	4.2	590	noreading	290	
14	280	0.25	5	4.4	486	noreading	300	
15	120	0.25	5	4.5	461	noreading	noreading	
16	300	0.25	5	4.6	416	noreading	340	
17	300	0.25	4.9	4.5	375	330	noreading	
18	300	0.25	5	4.5	321	310	noreading	
19	300	0.25	4.7	4.3	277	277	260	

20	315	0.25	4.6	4.1	254	242	240
21	315	0.25	4.5	4	225	232 noreading	

lost power in mains

10V 30 amps, not enough power for flow, and since losi
temperature at this power, shutting down and rebuilding

Analysis

Time	Power	flowrate	Ti	Tf	Cp	q calc	qeff	Pc	C*
8	518	0.2	285.16	809.16	892	93.4816	18.046641	420000	411.6
9	518	0.25	285.16	819.16	892	119.082	22.988803	420000	329.28
10	518	0.25	285.16	827.16	892	120.866	23.333205	420000	329.28
11	518	0.25	285.16	834.16	892	122.427	23.634556	420000	329.28
12	518	0.25	285.16	842.16	892	124.211	23.978958	420000	329.28
13	504	0.25	285.16	863.16	892	128.894	25.574206	420000	329.28
14	280	0.25	285.16	759.16	892	105.702	37.750714	440000	344.96
15	120	0.25	285.16	734.16	892	100.127	83.439167	450000	352.8
16	300	0.25	285.16	689.16	892	90.092	30.030667	460000	360.64
17	300	0.25	285.16	648.16	892	80.949	26.983	450000	352.8
18	300	0.25	285.16	594.16	892	68.907	22.969	450000	352.8
19	300	0.25	285.16	550.16	892	59.095	19.698333	430000	337.12
20	315	0.25	285.16	527.16	892	53.966	17.132063	410000	321.44
21	315	0.25	285.16	498.16	892	47.499	15.079048	400000	313.6

N_2O Resistojet Test **#4**

Note: Test date 17 Mar 97. Let apparatus cool and then went back and reassembled it. Reassembled with new heater. Last heater has bubble on outside end near end. post inspection - cut it open , we discovered that the heater had failed internally. silcoset was charred. heater could be getting too hot for input energy. water was a better coolant ? Going for higher mass flow. Tambient = 14 C. Put flow on right away.

Time	Power	Massflow	Pi	Pc	Tc	Te	Tstream
0	0	0.25	8.2	2.4			
1	494	0.25	8.4	2.4	146		
2	468	0.24	8.5	2.5	229		
3	468	0.25	8.9	3	297		
4	468	0.25	8.9	3	340		
5	468	0.25	9	3.3	380		155
6	468	0.25	9	3.5	419		180
7	468	0.25	9.1	3.6	443	207	195
8	468	0.25	9.1	3.7	469	226	210
9	468	0.25	9.1	3.8	489		245
10	468	0.25	9.1	3.8	501	260	253
11	468	0.25	9.2	3.9	515		
12	468	0.25	9.2	4	526	280	245
13	468	0.25	9.2	4	534	294	280
14	468	0.25	9.2	4	543	304	275

15	468	0.25	9.25	4.1	554	312	310
16	468	0.25	9.25	4.1	558	321	
17 off		oscillations in current, shut off					
18	0	0.25	9.3	4.5	450	325	310
19	0	0.26	9.3	4.55	358	309	280
20	0	0.27	9.3	4.5	304	281	
21	0	0.25	8.7	4.1	230	266	
22	0	0.26	8.7	4.1	198	243	220
23	0	0.26	8.5	4	164	220	210
26	480	0.25	8.8	3.5	178		
27	480	0.25	8.8	3.5	228		
28	480	0.25	8.9	3.55	275		
29	480	0.25	9	3.6	301		220
30	480	0.25	9.1	3.2	341	248	230

shut off at 32 — oscillation in amps, down to zero as I increased the voltage, smell burning
this heater had no degradatin on outside, which helps back up
internal failure from last time

Time	Power	Mass flow	Ti	Tf	Pc	Cp	Cp1	Q calc	Q calc 1
1	494	0.00025	287.16	419.16	240000	874.74	892	28.86642	29.436
2	468	0.00024	287.16	502.16	250000	874.74	892	45.136584	46.0272
3	468	0.00025	287.16	570.16	300000	874.74	892	61.887855	63.109
4	468	0.00025	287.16	613.16	300000	874.74	892	71.29131	72.698
5	468	0.00025	287.16	653.16	330000	874.74	892	80.03871	81.618
6	468	0.00025	287.16	692.16	350000	874.74	892	88.567425	90.315
7	468	0.00025	287.16	716.16	360000	874.74	892	93.815865	95.667
8	468	0.00025	287.16	742.16	370000	874.74	892	99.501675	101.465
9	468	0.00025	287.16	762.16	380000	874.74	892	103.87538	105.925
10	468	0.00025	287.16	774.16	380000	874.74	892	106.4996	108.601
11	468	0.00025	287.16	788.16	390000	874.74	892	109.56119	111.723
12	468	0.00025	287.16	799.16	400000	874.74	892	111.96672	114.176
13	468	0.00025	287.16	807.16	400000	874.74	892	113.7162	115.96
14	468	0.00025	287.16	816.16	400000	874.74	892	115.68437	117.967
15	468	0.00025	287.16	827.16	410000	874.74	892	118.0899	120.42
16	468	0.00025	287.16	831.16	410000	874.74	892	118.96464	121.312
18	0	0.00025	287.16	723.16	450000	874.74	892	95.34666	97.228
19	0	0.00026	287.16	631.16	455000	874.74	892	78.236746	79.78048
20	0	0.00027	287.16	577.16	450000	874.74	892	68.492142	69.8436
21	0	0.00025	287.16	503.16	410000	874.74	892	47.23596	48.168
22	0	0.00026	287.16	471.16	410000	874.74	892	41.847562	42.67328
23	0	0.00026	287.16	437.16	400000	874.74	892	34.11486	34.788
26	480	0.00025	287.16	451.16	350000	874.74	892	35.86434	36.572
27	480	0.00025	287.16	501.16	350000	874.74	892	46.79859	47.722
28	480	0.00025	287.16	548.16	355000	874.74	892	57.076785	58.203
29	480	0.00025	287.16	574.16	360000	874.74	892	62.762595	64.001
30	480	0.00025	287.16	614.16	320000	874.74	892	71.509995	72.921

Time	Q eff	Q eff 1	C* eff (Tc)	C* eff (Te)	Qeff Te
1	5.8434049	5.9587045	44.643218		
2	9.6445692	9.8348718	44.256991		
3	13.223901	13.484829	47.847258		
4	15.233186	15.533761	46.139036		
5	17.102288	17.439744	49.174315		
6	18.924663	19.298077	50.66394		
7	20.046125	20.441667	51.230859	62.566762	9.1963675
8	21.261042	21.680556	51.723407	63.069009	10.101709
9	22.195593	22.633547	52.419719		
10	22.756324	23.205342	52.011862	62.674227	11.721795
11	23.41051	23.872436	52.904374		
12	23.924513	24.396581	53.886167	64.769236	12.674786
13	24.298333	24.777778	53.618461	63.964847	13.34188
14	24.718881	25.206624	53.322009	63.408291	13.818376
15	25.232885	25.730769	54.290428	64.547691	14.199573
16	25.419795	25.921368	54.159632	64.056959	14.628419
18			63.727882	70.070949	
19			66.319691	69.054351	
20			66.050303	67.407053	
21			69.608932	67.244875	
22			69.167245	66.08342	
23			70.055238	65.957912	
26	7.4717375	7.6191667	62.753351		
27	9.7497063	9.9420833	59.54071		
28	11.890997	12.125625	57.744264		
29	13.075541	13.333542	57.216357		
30	14.897916	15.191875	49.174888	53.382463	10.87125

N20 Test 26/3/97 #2

Note: 26/3/97 New heater test. Lost heater in last run, reassembled going with ISE heater. Can monitor internal, especially if weird stuff happens. drilled out, lost disk. No silcoset set in. Drilled out one end nozzle tap. No sintered disk. Go for ss at its max power , watch temp. T ambient = 9 C.

No cooling purge, better heater. Thought Pi off, but no sintered disk (lok at early results).

Time	Power	massflow	Pi	Pc	Tc	Te	Ts	Th
0	216	0	0	0	0	0	0	9
1	216	0	0	0	0	0	0	415
2	204	0	0	0	0	0	0	574
3	204	0.25	2.5	2.5	0	0	0	725
4	204	0.25	2.6	2.6	0	0	0	774
5	204	0.25	2.9	2.9	0	0	0	817
6	204	0.25	3	3	316	0	0	845
7	204	0.25	3	3.2	331	0	0	861
8	204	0.25	3.5	3.3	343	0	0	874
9	204	0.25	3.5	3.4	353	0	0	882
10	204	0.25	3.5	3.4	362	0	0	889

11	204	0.25	3.5	3.5	370	0	0	892	
12	204	0.25	3.5	3.5	375	0	0	897	
13	204	0.25	3.5	3.5	380	0	0	899	
14	204	0.25	3.6	3.5	384	0	0	901	
15	204	0.25	3.5	3.6	388	0	0	902	
16	204	0.25	3.5	3.6	391	0	0	903	
17	204	0.25	3.5	3.7	393	0	165	902	
18	204	0.25	3.5	3.7	394	166	0	902	
19	204	0.25	3.5	3.7	395	0	0	903	
20	204	0.25	3.5	3.7	396	0	0	902	
21	204	0.25	3.5	3.75	397	0	0	902	
22	204	0.25	3.5	3.8	398	0	0	903	
23	204	0.25	3.5	3.8	399	0	0	903	adding insula
24	204	0.25	3.5	3.8	399	0	0	903	
25	204	0.25	3.5	3.8	400	0	0	904	
26	204	0.25	3.5	3.8	404	0	0	904	
27	204	0.25	3.7	3.8	407	0	0	906	
28	204	0.25	3.75	3.8	410	0	0	907	
29	204	0.25	3.75	3.8	414	0	0	908	
30	204	0.25	3.75	3.85	416	0	0	909	adding anoth
31	204	0.25	3.75	3.85	419	0	0	911	
32	204	0.25	3.75	3.9	422	0	0	912	
33	204	0.25	3.9	3.9	424	0	0	914	
34	204	0.25	3.9	3.9	426	0	0	915	
35	204	0.25	3.9	3.9	428	0	0	916	
36	204	0.25	3.9	3.9	429	0	0	917	
37	204	0.25	3.9	3.9	431	0	0	918	
38	204	0.25	3.9	3.9	432	0	0	918	
39	204	0.25	4	3.9	434	0	0	919	
40	204	0.25	4	3.9	435	0	0	919	up in power
41	204	0.25	4	4	436	0	0	919	
42	247	0.25	4	4	444	0	0	977	
43	247	0.25	4	4	465	0	0	1007	
44	247	0.25	4	4	477	0	0	1025	
45	247	0.25	4	4	489	0	0	1038	
46	247	0.25	4	4	498	0	0	1044	
47	247	0.25	4	4.1	504	0	0	1050	
48	247	0.25	4	4.1	511	0	0	1054	
49	247	0.25	4	4.1	516	0	0	1058	
50	247	0.25	4	4.2	520	0	0	1061	
51	247	0.25	4	4.2	524	0	0	1064	
52	247	0.25	4	4.2	527	0	0	1067	
53	247	0.25	4.2	4.2	530	0	0	1069	
54	247	0.25	4.25	4.25	532	0	0	1071	
55	247	0.25	4.25	4.3	536	0	0	1072	
56	247	0.25	4.25	4.3	538	0	0	1073	
57	247	0.25	4.25	4.3	539	0	0	1075	
58	247	0.25	4.25	4.3	541	0	0	1076	
59	247	0.25	4.25	4.3	543	0	0	1078	

60	247	0.25	4.25	4.3	544	0	0	1079	
61	247	0.25	4.25	4.3	546	282	0	1080	
62	247	0.25	4.25	4.3	548	283	0	1081	
63	247	0.25	4.25	4.3	550	284	0	1083	
64	247	0.25	4.25	4.35	551	285	0	1084	
65	247	0.25	4.25	4.35	553	286	0	1085	
66	247	0.25	4.25	4.4	554	288	0	1086	
67	247	0.25	4.5	4.4	555	289	0	1087	
68	247	0.25	4.5	4.4	557	290	0	1089	
69	247	0.25	4.5	4.4	558	291	0	1090	
70	247	0.25	4.5	4.4	559	291	0	1091	
71	247	0.25	4.5	4.4	561	292	0	1092	
72	247	0.25	4.5	4.4	562	294	0	1093	
73	247	0.25	4.5	4.5	563	295	0	1094	
74	247	0.25	4.5	4.5	564	296	0	1095	
75	247	0.25	4.5	4.5	565	297	0	1096	
76	247	0.25	4.5	4.5	565	298	0	1097	
77	247	0.25	4.5	4.5	566	298	0	1097	
78	247	0.25	4.5	4.5	566	299	0	1098	
79	247	0.25	4.5	4.5	567	299	0	1099	
80	247	0.25	4.5	4.5	570	297	0	1100	
81	247	0.25	4.5	4.5	572	296	0	1101	
82	247	0.25	4.5	4.5	574	296	0	1102	
83	247	0.25	4.5	4.5	576	296	0	1103	
84	247	0.25	4.5	4.5	579	297	0	1104	
85	247	0.25	4.5	4.5	580	297	0	1105	
86	247	0.25	4.5	4.55	582	298	0	1107	
87	247	0.25	4.5	4.56	584	299	0	1108	
88	247	0.25	4.5	4.58	586	299	0	1109	
89	247	0.25	4.5	4.6	587	300	0	1110	
90	247	0.25	4.5	4.9	588	301	0	1111	
91	247	0.25	4.5	4.9	590	302	0	1112	
92	247	0.25	4.5	4.9	591	302	0	1113	
93	247	0.25	4.5	4.9	593	303	0	1114	
94	247	0.25	4.5	4.9	594	304	0	1115	
95	247	0.25	4.5	4.9	596	305	0	1116	
96	247	0.25	4.5	4.9	594	305	0	1116	added a dres
97	247	0.25	4.5	4.9	592	305	0	1116	
98	247	0.25	4.5	4.9	590	308	0	1116	increase flow
99	247	0.275	5	5.3	587	317	0	1115	
100	247	0.275	5	5.4	582	325	0	1111	
101	0	0.275	6.2	6.2	517	0	0	0	shirt on fire, t
102	0	0.275	6	6	477	0	0	0	malcolm pulle
103	0	0.275	5.5	5.5	420	0	0	518	heater surviv
104	0	0.275	5.4	5.4	336	0	0	0	fire coming o
									let gas on aw
									since heater
									just some ch
Time	Power	Massflow	Ti	Tf	Q calc	C*(Tc)	C*	Te	C*(Te)

3	204	0.00025	282.16	998.16	159.668	650.40216	196		
4	204	0.00025	282.16	1047.16	170.595	666.17513	203.84		
5	204	0.00025	282.16	1090.16	180.184	679.71525	227.36		
6	204	0.00025	282.16	589.16	68.461	499.68754	235.2		
7	204	0.00025	282.16	604.16	71.806	506.00858	250.88		
8	204	0.00025	282.16	616.16	74.482	511.00911	258.72		
9	204	0.00025	282.16	626.16	76.712	515.13915	266.56		
10	204	0.00025	282.16	635.16	78.719	518.82807	266.56		
11	204	0.00025	282.16	643.16	80.503	522.08523	274.4		
12	204	0.00025	282.16	648.16	81.618	524.11068	274.4		
13	204	0.00025	282.16	653.16	82.733	526.12833	274.4		
14	204	0.00025	282.16	657.16	83.625	527.73689	274.4		
15	204	0.00025	282.16	661.16	84.517	529.34057	282.24		
16	204	0.00025	282.16	664.16	85.186	530.54015	282.24		
17	204	0.00025	282.16	666.16	85.632	531.33836	290.08	438.16	430.92159
18	204	0.00025	282.16	667.16	85.855	531.73702	290.08	439.16	431.41305
19	204	0.00025	282.16	668.16	86.078	532.13537	290.08		
20	204	0.00025	282.16	669.16	86.301	532.53344	290.08		
21	204	0.00025	282.16	670.16	86.524	532.9312	294		
22	204	0.00025	282.16	671.16	86.747	533.32867	297.92		
23	204	0.00025	282.16	672.16	86.97	533.72584	297.92		
24	204	0.00025	282.16	672.16	86.97	533.72584	297.92		
25	204	0.00025	282.16	673.16	87.193	534.12271	297.92		
26	204	0.00025	282.16	677.16	88.085	535.70727	297.92		
27	204	0.00025	282.16	680.16	88.754	536.89262	297.92		
28	204	0.00025	282.16	683.16	89.423	538.07537	297.92		
29	204	0.00025	282.16	687.16	90.315	539.64832	297.92		
30	204	0.00025	282.16	689.16	90.761	540.43308	301.84		
31	204	0.00025	282.16	692.16	91.43	541.60809	301.84		
32	204	0.00025	282.16	695.16	92.099	542.78056	305.76		
33	204	0.00025	282.16	697.16	92.545	543.56079	305.76		
34	204	0.00025	282.16	699.16	92.991	544.33991	305.76		
35	204	0.00025	282.16	701.16	93.437	545.11792	305.76		
36	204	0.00025	282.16	702.16	93.66	545.50651	305.76		
37	204	0.00025	282.16	704.16	94.106	546.28285	305.76		
38	204	0.00025	282.16	705.16	94.329	546.67061	305.76		
39	204	0.00025	282.16	707.16	94.775	547.44531	305.76		
40	204	0.00025	282.16	708.16	94.998	547.83224	305.76		
41	204	0.00025	282.16	709.16	95.221	548.21891	313.6		
42	247	0.00025	282.16	717.16	97.005	551.30245	313.6		
43	247	0.00025	282.16	738.16	101.688	559.31588	313.6		
44	247	0.00025	282.16	750.16	104.364	563.84385	313.6		
45	247	0.00025	282.16	762.16	107.04	568.33574	313.6		
46	247	0.00025	282.16	771.16	109.047	571.6815	313.6		
47	247	0.00025	282.16	777.16	110.385	573.90117	321.44		
48	247	0.00025	282.16	784.16	111.946	576.47999	321.44		
49	247	0.00025	282.16	789.16	113.061	578.31496	321.44		
50	247	0.00025	282.16	793.16	113.953	579.77875	329.28		
51	247	0.00025	282.16	797.16	114.845	581.23886	329.28		

52	247	0.00025	282.16	800.16	115.514	582.33154	329.28		
53	247	0.00025	282.16	803.16	116.183	583.42217	329.28		
54	247	0.00025	282.16	805.16	116.629	584.14813	333.2		
55	247	0.00025	282.16	809.16	117.521	585.59734	337.12		
56	247	0.00025	282.16	811.16	117.967	586.32061	337.12		
57	247	0.00025	282.16	812.16	118.19	586.6819	337.12		
58	247	0.00025	282.16	814.16	118.636	587.40383	337.12		
59	247	0.00025	282.16	816.16	119.082	588.12487	337.12		
60	247	0.00025	282.16	817.16	119.305	588.48506	337.12		
61	247	0.00025	282.16	819.16	119.751	589.20478	337.12	555.16	485.05499
62	247	0.00025	282.16	821.16	120.197	589.92362	337.12	556.16	485.49165
63	247	0.00025	282.16	823.16	120.643	590.64159	337.12	557.16	485.92793
64	247	0.00025	282.16	824.16	120.866	591.00024	341.04	558.16	486.36381
65	247	0.00025	282.16	826.16	121.312	591.7169	341.04	559.16	486.7993
66	247	0.00025	282.16	827.16	121.535	592.07491	344.96	561.16	487.66911
67	247	0.00025	282.16	828.16	121.758	592.4327	344.96	562.16	488.10344
68	247	0.00025	282.16	830.16	122.204	593.14763	344.96	563.16	488.53737
69	247	0.00025	282.16	831.16	122.427	593.50477	344.96	564.16	488.97093
70	247	0.00025	282.16	832.16	122.65	593.86169	344.96	564.16	488.97093
71	247	0.00025	282.16	834.16	123.096	594.5749	344.96	565.16	489.4041
72	247	0.00025	282.16	835.16	123.319	594.93119	344.96	567.16	490.26929
73	247	0.00025	282.16	836.16	123.542	595.28726	352.8	568.16	490.70131
74	247	0.00025	282.16	837.16	123.765	595.64312	352.8	569.16	491.13296
75	247	0.00025	282.16	838.16	123.988	595.99876	352.8	570.16	491.56422
76	247	0.00025	282.16	838.16	123.988	595.99876	352.8	571.16	491.99511
77	247	0.00025	282.16	839.16	124.211	596.3542	352.8	571.16	491.99511
78	247	0.00025	282.16	839.16	124.211	596.3542	352.8	572.16	492.42562
79	247	0.00025	282.16	840.16	124.434	596.70942	352.8	572.16	492.42562
80	247	0.00025	282.16	843.16	125.103	597.77382	352.8	570.16	491.56422
81	247	0.00025	282.16	845.16	125.549	598.48237	352.8	569.16	491.13296
82	247	0.00025	282.16	847.16	125.995	599.19008	352.8	569.16	491.13296
83	247	0.00025	282.16	849.16	126.441	599.89696	352.8	569.16	491.13296
84	247	0.00025	282.16	852.16	127.11	600.95571	352.8	570.16	491.56422
85	247	0.00025	282.16	853.16	127.333	601.30821	352.8	570.16	491.56422
86	247	0.00025	282.16	855.16	127.779	602.0126	356.72	571.16	491.99511
87	247	0.00025	282.16	857.16	128.225	602.71617	357.504	572.16	492.42562
88	247	0.00025	282.16	859.16	128.671	603.41891	359.072	572.16	492.42562
89	247	0.00025	282.16	860.16	128.894	603.76998	360.64	573.16	492.85575
90	247	0.00025	282.16	861.16	129.117	604.12084	384.16	574.16	493.28551
91	247	0.00025	282.16	863.16	129.563	604.82195	384.16	575.16	493.7149
92	247	0.00025	282.16	864.16	129.786	605.17221	384.16	575.16	493.7149
93	247	0.00025	282.16	866.16	130.232	605.8721	384.16	576.16	494.14391
94	247	0.00025	282.16	867.16	130.455	606.22175	384.16	577.16	494.57255
95	247	0.00025	282.16	869.16	130.901	606.92043	384.16	578.16	495.00082
96	247	0.00025	282.16	867.16	130.455	606.22175	384.16	578.16	495.00082
97	247	0.00025	282.16	865.16	130.009	605.52226	384.16	578.16	495.00082
98	247	0.00025	282.16	863.16	129.563	604.82195	384.16	581.16	496.2834
99	247	0.000275	282.16	860.16	141.7834	603.76998	377.74545	590.16	500.11143
100	247	0.000275	282.16	855.16	140.5569	602.0126	384.87273	598.16	503.48969

101	0	0.000275	282.16	790.16	124.6124	578.68125	441.89091
102	0	0.000275	282.16	750.16	114.8004	563.84385	427.63636
103	0	0.000275	282.16	693.16	100.8183	541.99919	392
104	0	0.000275	282.16	609.16	80.2131	508.09811	384.87273

Time	Q eff	C* eff	C*eff Te	Q eff Te
3	78.268627	30.135201		
4	83.625	30.59856		
5	88.32549	33.449301		
6	33.559314	47.069415		
7	35.19902	49.580187		
8	36.510784	50.629234		
9	37.603922	51.745242		
10	38.587745	51.377328		
11	39.462255	52.558468		
12	40.008824	52.355354		
13	40.555392	52.154576		
14	40.992647	51.995607		
15	41.429902	53.31917		
16	41.757843	53.198613		
17	41.976471	54.594214	67.31619	17.052941
18	42.085784	54.553283	67.239505	17.162255
19	42.195098	54.512444		
20	42.304412	54.471697		
21	42.413725	55.166596		
22	42.523039	55.860489		
23	42.632353	55.81892		
24	42.632353	55.81892		
25	42.741667	55.777445		
26	43.178922	55.612461		
27	43.506863	55.48968		
28	43.834804	55.367709		
29	44.272059	55.206324		
30	44.490686	55.851503		
31	44.818627	55.730334		
32	45.146569	56.332158		
33	45.365196	56.251298		
34	45.583824	56.170784		
35	45.802451	56.090616		
36	45.911765	56.05066		
37	46.130392	55.971004		
38	46.239706	55.931304		
39	46.458333	55.852155		
40	46.567647	55.812706		
41	46.676961	57.203427		
42	39.273279	56.883476		
43	41.169231	56.068496		

44	42.252632	55.618236		
45	43.336032	55.178652		
46	44.148583	54.855719		
47	44.690283	56.009643		
48	45.322267	55.759091		
49	45.773684	55.582169		
50	46.134818	56.794078		
51	46.495951	56.651408		
52	46.766802	56.545108		
53	47.037652	56.439405		
54	47.218219	57.040327		
55	47.579352	57.568567		
56	47.759919	57.497553		
57	47.850202	57.462144		
58	48.030769	57.391522		
59	48.211336	57.32116		
60	48.301619	57.286076		
61	48.482186	57.2161	69.501398	24.647368
62	48.662753	57.146381	69.438887	24.737652
63	48.84332	57.076915	69.376544	24.827935
64	48.933603	57.70556	70.120349	24.918219
65	49.11417	57.63567	70.05762	25.008502
66	49.204453	58.262898	70.736488	25.189069
67	49.294737	58.227711	70.673545	25.279352
68	49.475304	58.157529	70.61077	25.369636
69	49.565587	58.122532	70.548161	25.459919
70	49.65587	58.087599	70.548161	25.459919
71	49.836437	58.017921	70.485719	25.550202
72	49.926721	57.983176	70.361331	25.730769
73	50.017004	59.265505	71.897097	25.821053
74	50.107287	59.230098	71.833908	25.911336
75	50.197571	59.194754	71.770886	26.001619
76	50.197571	59.194754	71.70803	26.091903
77	50.287854	59.159473	71.70803	26.091903
78	50.287854	59.159473	71.645338	26.182186
79	50.378138	59.124255	71.645338	26.182186
80	50.648988	59.018978	71.770886	26.001619
81	50.829555	58.949105	71.833908	25.911336
82	51.010121	58.879479	71.833908	25.911336
83	51.190688	58.8101	71.833908	25.911336
84	51.461538	58.706489	71.770886	26.001619
85	51.551822	58.672074	71.770886	26.001619
86	51.732389	59.254573	72.504786	26.091903
87	51.912955	59.315482	72.600609	26.182186
88	52.093522	59.506255	72.919033	26.182186
89	52.183806	59.731357	73.17354	26.27247
90	52.274089	63.589927	77.877819	26.362753
91	52.454656	63.516213	77.810089	26.453036
92	52.544939	63.479452	77.810089	26.453036

93	52.725506	63.406121	77.742535	26.54332
94	52.815789	63.369551	77.675156	26.633603
95	52.996356	63.2966	77.607953	26.723887
96	52.815789	63.369551	77.607953	26.723887
97	52.635223	63.442755	77.607953	26.723887
98	52.454656	63.516213	77.407384	26.994737
99	57.402186	62.564464	75.532258	30.588016
100	56.905628	63.931008	76.441035	31.38251
101		76.361711		
102		75.843049		
103		72.324831		
104		75.747718		

Mark-II 23 Oct 1997

Time	Msflw FP	Tf	Ti	Cp	Q calc	Pow	C*	C* (T)
5	2.591E-05	461.16	290.16	892	3.9527905	146.268	441.4517	442.08696
10	2.295E-05	611.16	292.16	892	6.5303766	148.512	498.47495	508.93153
15	2.128E-05	713.16	293.16	892	7.9715899	147.492	537.64452	549.76284
20	1.962E-05	804.16	294.16	892	8.9264402	146.676	583.01906	583.78526
25	1.798E-05	873.16	294.16	892	9.2871276	135.436	636.19175	608.3154
30	1.757E-05	922.16	295.16	892	9.8291367	135.436	650.94313	625.15115
35	1.717E-05	957.16	296.16	892	10.122459	135.044	666.35601	636.90428
40	1.676E-05	981.16	296.16	892	10.242223	135.044	682.47576	644.83977
45	1.636E-05	996.16	296.16	892	10.213935	134.456	692.62746	649.75023
50	1.636E-05	1006.16	297.16	892	10.345257	134.456	692.62746	653.00336
55	1.636E-05	1014.16	297.16	892	10.461988	134.064	692.62746	655.59425
60	1.595E-05	1019.16	298.16	892	10.260849	100.3	710.14447	657.20836
65	1.636E-05	1011.16	298.16	892	10.403623	100.3	692.62746	654.62387
70	1.636E-05	997.16	298.16	892	10.199344	100.3	692.62746	650.07628
75	1.676E-05	986.16	298.16	892	10.287079	100.3	669.35123	646.48073
80	1.676E-05	977.16	298.16	892	10.15251	100.3	669.35123	643.52398
85	1.717E-05	969.16	298.16	892	10.275597	100.3	653.54147	640.8843
90	1.717E-05	964.16	298.16	892	10.199028	100.3	653.54147	639.22897
95	1.717E-05	959.16	299.16	892	10.107145	100.3	653.54147	637.56934
100	1.717E-05	954.16	298.16	892	10.04589	100.64	653.54147	635.90538
105	1.717E-05	951.16	298.16	892	9.999948	100.64	653.54147	634.90491
110	1.717E-05	949.16	299.16	892	9.9540064	100.64	653.54147	634.23705
115	1.717E-05	947.16	298.16	892	9.9386925	100.64	653.54147	633.56849
120	1.717E-05	946.16	298.16	892	9.9233787	100.98	653.54147	633.23394
125	1.717E-05	945.16	298.16	892	9.9080648	101.32	653.54147	632.89922
130	1.757E-05	944.16	298.16	892	10.126989	101.66	638.42499	632.56432
135	1.757E-05	944.16	298.16	892	10.126989	101.66	632.16592	632.56432
140	1.757E-05	944.16	299.16	892	10.111313	101.66	632.16592	632.56432
145	1.636E-05	943.16	299.16	892	9.3968204	101.66	632.10661	632.22924
150	1.515E-05	942.16	299.16	892	8.6896602	101.49	638.92281	631.89399
155	1.515E-05	940.16	299.16	892	8.6626317	101.49	638.92281	631.22295
160	1.757E-05	941.16	299.16	892	10.064283	101.83	632.16592	631.55856
165	0.0000188	915.16	299.16	892	10.330074	0	590.95745	622.77391

170	1.962E-05	838.16	298.16	892	9.451525	0	566.2012	595.99876
175	2.045E-05	779.16	298.16	892	8.7732553	0	543.32942	574.63916
180	2.128E-05	723.16	298.16	892	8.0664898	0	522.13554	553.60384
185	2.211E-05	676.16	297.16	892	7.4753596	0	502.44211	535.31157
190	2.253E-05	637.16	297.16	892	6.83305	0	497.99161	519.64427
195	2.337E-05	602.16	297.16	892	6.3581782	0	480.09242	505.17034
200	2.379E-05	571.16	296.16	892	5.8361776	0	471.58709	491.99511
205	2.464E-05	546.16	296.16	892	5.494274	0	455.39411	481.10718
210	2.506E-05	522.16	296.16	892	5.0523995	0	447.6808	470.41774
215	2.549E-05	501.16	296.16	892	4.6607357	0	440.20716	460.86114
220	2.634E-05	483.16	296.16	892	4.393951	0	425.93577	452.50917

Time	Pow eff	C* eff
5	2.7024301	99.856303
10	4.3972047	97.945385
15	5.4047609	97.795718
20	6.085822	99.868753
25	6.8572075	104.58255
30	7.2574032	104.12572
35	7.4956746	104.6242
40	7.5843597	105.83649
45	7.596489	106.59903
50	7.6941581	106.06798
55	7.8037265	105.6488
60	10.230159	108.05469
65	10.372505	105.80541
70	10.168837	106.54557
75	10.25631	103.53769
80	10.122143	104.01341
85	10.244863	101.97495
90	10.168523	102.23903
95	10.076914	102.50516
100	9.9820047	102.77338
105	9.9363553	102.93533
110	9.8907059	103.04372
115	9.8754894	103.15246
120	9.8270734	103.20696
125	9.7789823	103.26154
130	9.9616263	100.92649
135	9.9616263	99.937018
140	9.9462058	99.937018
145	9.2433803	99.980604
150	8.5620851	101.11234
155	8.5354534	101.21983
160	9.8834169	100.09617

Mark-II Resistojet 2 23 Oct 97 4

Note: Hybrid start up test. flow goes out to fittings good nozzle

waited until last run was some what cooled then do 5 minute run and see how long
it takes to get t's or what t we get in 5 minutes. wait for th to hit 950 and then
go with flow
flow 0 at start

n20 test #2 | 28 V 9.82 amp - more accurate than last time | run

Time	Power	Flow	Pi	Pc	Th	Tc	Vac	Ta	Comments
0	270.756	0	10.6	10.3	105	97	0.326	0	flow on at2:4
1	274.68	0	10.6	10.3	571	0	0	0	
2	272.014	0	10.6	10.3	765	0	0	0	
3	272.014	3.85	10.6	10.3	881	163	0.344	16	
4	271.737	3.7	10.6	10.3	947	204	0.343	17	
5	271.737	3.6	10.6	10.3	1019	255	0.342	17	
6	272.996	3.4	10.6	10.3	1059	301	0.341	17	
7	273.978	3.3	10.6	10.3	1100	346	0.34	18	
8	273.978	3.2	10.6	10.3	1129	396	0.339	18	
9	274.96	3.05	10.6	10.3	1132	446	0.339	19	
10	275.942	3	10.6	10.3	1132	489	0.338	19	faint glow ligh
11	0	2.9	10.6	10.3	955	525	0.336	20	
12	0	3	10.6	10.3	815	548	0.335	20	
13	0	3.05	10.6	10.3	724	563	0.335	20	
14	0	3.05	10.6	10.3	668	566	0.333	20	
									stopeed takin
									power off at 1
									dropped at 1

checked nozzle flow at fittings

tore down left thruster in RO vacuum

15 Jan 98 N20 Run using Mark-III #3 (with catalyst pack)
has insulation
had oscillations in this run

					38.5 J/mol K	0.8747614
Thrust1	mdot1	tc	297.99	Isp 1	Qeff	highest readi
0.0357039	0.0000548	173		66.414964	2.4612738	66.414964
Thrust2	mdot2	tc	297	Isp 2	Q eff	Highest readi
0.0307635	0.000036	536.4		87.109167	5.4754764	84.979947
Thrust 3	mdot3	tc	301.95	Isp 3	Qeff	Highest readi
0.0287873	3.067E-05	734		95.673122	6.3444634	93.01065

Thrust 4	mdot4	tc	301.95	Isp 4	Qeff	highest readi
0.0281286	2.128E-05	783.1		134.75599	4.703995	83.820685

Thrust 5	mdot5	tc	527.67 lost heater	Isp 5
0.0277992	2.086E-05	782.1		135.83051
Thrust 6	mdot6	tc	0 stable, but float could be sticking	Isp 6
0.0304341	3.963E-05	709		78.279067
Thrust 7	mdot	tc	0 stable, but float could be sticking	Isp 7
0.0327396	4.333E-05	425.9		77.025803

12 Jan 98 test Mark-III #1

Thrust1	mdot1	Tc1	Pow1	Isp1	Qeff1
0.0339887	4.614E-05	182	206.64	75.087664	3.1643605
thrust 2	mdot2	tc2	pow2	isp2	qeff2
0.0309334	3.421E-05	495.4	202.54	92.17873	7.0236841
thrust3	mdot3	tc3	pow3	isp3	qeff3
0.0278781	2.763E-05	628.1	203.36	102.85029	7.2274839
thrust4	mdot4	tc4	pow4	isp4	qeff4
0.0261807	2.634E-05	669	204.18	101.31273	7.3243512
thrust5	mdot5	tc5	pow5	isp5	qeff5
0.0261807	2.634E-05	641.7	149.1	101.31273	9.6081746
thrust6	mdot6	tc6	pow6	isp6	qeff6
0.0261807	2.634E-05	633.1	149.1	101.31273	9.4752643
thrust7	mdot7	tc7	pow7	isp7	qeff7
0.0258413	0.0000272	618.4	124.16	96.844669	11.467472
thrust8	mdot8	tc8	pow8	isp8	qeff8
0.0261807	0.0000272	608.4	98.04	98.116912	14.279966

14 Jan 98 Mark-III #3 (catalyst)
Test with no insulatin for a comparison
notice we got a nozzle clog in this run and this thruster has only seen N2O
malcolm was able to fix with a poke, why broken down into two sections - no insulation on both

Thrust1	Mdot1	Tc1	Pow1	Isp1	Qeff1	
0.0169101	2.936E-05	179.4	299.97	58.706105	1.3648758	
Thrust1h	mdot1h	Tc1h	Pow1h	Isp1h	Qeff1h	mass flow varied, but thrust
0.0169101	3.155E-05	179.4	299.97	54.635753	1.4665588	
Thrust1l	mdot1l	Tc1l	Pow1l	Isp1l	Qeff1l	
0.0169101	0.0000272	179.4	299.97	63.373456	1.2643549	
Thrust2	Mdot2	Tc2	Pow2	Isp2	Qeff2	
0.0065804	1.237E-05	377	296.01	54.235446	1.3048209	

Thrust3	Mdot3	Tc3	Pow3	Isp3	Qeff3
0.0049912	0.0000108	390.5	296.01	47.11	1.1824838
Thrust4	Mdot4	Tc4	Pow4	Isp4	Qeff4
0.0065804	1.355E-05	219.2	0	49.487919	#DIV/0!

Thrust1	Mdot1	Tc1	Pow1	Isp1	Qeff1
0.0365333	5.431E-05	197.4	298.98	68.570313	2.8189339
Thrust 2	Mdot2	Tc2	Pow2	Isp2	Qeff2
0.0333969	0.0000452	377.7	297	75.318053	4.7620126
Thrust2h	Mdot2h	Tc2h	Pow2h	Isp2h	Qeff2h
0.0333969	4.614E-05	377.7	297	73.780417	4.8612563
Thrust2l	Mdot2l	Tc2l	Pow2l	Isp2l	Qeff2l
0.0333969	4.426E-05	377.7	297	76.914193	4.6631903
Thrust3	Mdot3	Tc3	Pow3	Isp3	Qeff3
0.0333969	4.426E-05	396.9	297	76.914193	4.9134929
Thrust4	mdot4	Tc4	Pow4	Isp4	Qeff4
0.0349651	4.851E-05	284.8	0	73.467355	#DIV/0!

13 Jan 98 Mark-III #3 Test first test of this thruster - has insulation on used first thrust cal since it was closest to zero

Thrust 1	mdot1	Tc1	Pow1	Isp1	Qeff1
0.0362062	5.236E-05	208.6	294.98	70.484412	2.9285889
Thrust2	Mdot2	Tc2	Pow2	Isp2	Qeff2
0.0313093	3.465E-05	554.3	293.02	92.096842	5.5275982
Thrust3	Mdot3	Tc3	Pow3	Isp3	Qeff3
0.0292106	3.067E-05	743.5	300.96	97.080073	6.4500157
Thrust4	Mdot4	Tc4	Pow4	Isp4	Qeff4
0.0299102	3.067E-05	712.4	195.2	99.404995	9.5171794
Thrust5	Mdot5	Tc5	Pow5	Isp5	Qeff5
0.0295604	3.155E-05	664.6	100.92	95.508558	17.627931
Thrust6	Mdot6	Tc6	Pow6	Isp6	Qeff6
0.0292106	3.243E-05	625.7	100.92	91.811791	17.02719
Thrust7	Mdot7	Tc7	Pow7	Isp7	Qeff7
0.033408	4.055E-05	506	0	83.982737	#DIV/0!

10 January 1998 Mark-II #1 used this test as a comparison to the previous day's run using Mark-II#2 (catalyst)
had to run at 17 bar inlet pressure due to clog before christmas in injector - used FP flow calibration for mass flow

Thrust1	mdot1	Tc1	Pow1	Isp1	Qeff1
0.0123149	2.038E-05	161.5	103.2	61.611779	2.4437905
Thrust2	mdot2	Tc2	Pow2	Isp2	Qeff2
0.0170614	2.09E-05	626.1	103.2	83.211368	10.737819
Thrust3	mdot3	Tc3	Pow3	Isp3	Qeff3
0.0170614	2.355E-05	403.8	0	73.84426	#DIV/0!

21 Jan 98 Mark-III #4 first n20 test on the big thruster - saw some oscillations in this run took averages
kept temp with out power, but shut off due to time

Thrust1	Mdot1	tc1	pow1	isp1	qeff1	
0.352975	0.00046	229.2	314.82	78.21987	26.739059	
thrust2	mdot2	tc2	pow2	isp2	qeff2	
0.5334572	0.000435	938.7	318	125.009	109.93216	surge then died down
thrust3	mdot3	tc3	pow3	isp3	qeff3	
0.447482	0.00044	612.8	318	103.67019	71.750126	
thrust4	mdot4	tc4	pow4	isp4	qeff4	
0.4579828	0.00044	548.4	318	106.10295	63.955409	
thrust5	mdot5	tc5	pow5	isp5	qeff5	
0.5236127	0.00036	916.8	345.28	148.265	81.792897	
thrust6	mdot6	tc6	pow6	isp6	qeff6	
0.4953918	0.00041	714.2	296.64	123.16746	83.932019	
thrust7	mdot7	tc7	pow7	isp7	qeff7	
0.4960481	0.0004	747.7	0	126.4139	#DIV/0!	
thrust8	mdot8	tc8	pow8	isp8	qeff8	
0.4776718	0.000395	795.7	0	123.27172	#DIV/0!	

22 Jan 98 N20 #2 on Mark III #4 ran for 20 hours with no power (over night)
thrust cal at zero, and had some oscillations, took averages

Thrust1	mdot1	tc1	pow1	isp1	qeff1
0.3984343	0.00046	267.3	314.82	88.293735	31.608839
thrust2	mdot2	tc2	pow2	isp2	qeff2
0.4555093	0.00044	502	318	105.5299	58.33934
thrust3	mdot3	tc3	pow3	isp3	qeff3
0.4712541	0.00044	542.9	318	109.17757	63.289711
thrust4	mdot4	tc4	pow4	isp4	qeff4
0.5119282	0.0004	728.7	0	130.4608	#DIV/0!
thrust5	mdot5	tc5	pow5	isp5	qeff5
0.5191446	0.0004	747.8	0	132.29984	#DIV/0!
thrust6	mdot6	tc6	pow6	isp6	qeff6
0.5257049	0.0004	733.5	0	133.97169	#DIV/0!
thrust7	mdot7	tc7	pow7	isp7	qeff7
0.5302971	0.000405	690.6	0	133.47356	#DIV/0!
thrust8	mdot8	tc8	pow8	isp8	qeff8
0.5237368	0.00039	678.2	0	136.89244	#DIV/0!

Time	Isp
0	88.293735
1	105.5299
3	109.17757
4	130.4608
5	132.29984
6	133.97169
9	130.4608
24	136.89244

Mark-II #2 first test of n20 catalyst on mark-II saw some fluctuations

Thurst1	mdot1	Tc1	Pow1	Isp1	Qeff1
0.0139791	2.086E-05	257.1	105	68.303415	4.1209517
Thrust2	mdot2	Tc2	Pow2	Isp2	
0.0092817	1.555E-05	578.7	104.4	60.837834	7.2803681
Thrust3	mdot3	Tc3	Pow3	Isp3	Qeff3
0.0100646	1.475E-05	609.7	105	69.556271	7.2464077
Thrust4	mdot4	Tc4	Pow4	Isp4	Qeff4
0.0092817	1.395E-05	653.5	120.96	67.81465	6.3919037
Thrust5	mdot5	Tc5	Pow5	Isp5	Qeff5

0.0092817	1.276E-05	654.54	120.96	74.135162	5.8565506
Thrust6	mdot6	Tc6	Pow6	Isp6	Qeff6
0.0108475	2.086E-05	265.7	0	53.002277	#DIV/0!